Characterization and Treatment of Emissions from a Mining Oil Sands Complex

Volume 1 and 2

Environment Canada Environnement Canada

2035110A VOL ISS 5 850200
EXC # 001

<REPORT> IP

OOFF

IP-5
February, 1985

CHARACTERIZATION AND TREATMENT
OF EMISSIONS FROM A
MINING OIL SANDS COMPLEX
VOLUME I

November 1983

DSS 7970-8

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IP-5

CHARACTERIZATION AND TREATMENT OF EMISSIONS FROM A MINING OIL SANDS COMPLEX

BY: MONENCO CONSULTANTS LIMITED

FOR: ENVIRONMENTAL PROTECTION SERVICE

ENVIRONMENT CANADA

November 1983

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Any comments concerning its content should be directed to:

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Funds for this study were provided through the inter-departmental panel on energy reserarch and development and the Unsolicited Proposal Programme of the Department of Supply and Services.

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30 November 1983
DSS 7970-8

Chemical Industries Division
Industrial Programs Branch
Environmental Protection Programs Directorate
Environmental Protection Service
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Attention: W. Richardson and A. Stelzig

Gentlemen:

We are pleased to present you with this final report on the characterization and treatment of emissions from a mining oil sands complex. This report contains, where appropriate, the comments received from the technical review completed by other government agencies and industry.

We would like at this time to express our gratitude to Environment Canada for the help and cooperation provided by their staff. We have found this project both challenging and entirely interesting and look forward to further opportunities to cooperate with you.

Should you have any further questions concerning the report, please do not hesitate to contact Martyn Riddle, the project manager, or myself.

Yours very truly,

S.W. Behie, Ph.D., P.Eng.
Manager
Environmental Division

PREFACE

This report fulfills the terms of reference for Monenco work order DSS7970-8, "Characterization and Treatment of Emissions from a Mining Oil Sands Complex" and the Supply and Services Canada file number 5255 KE 145-2-0438.

The data included in the report was collected and analyzed by B. Amero (Junior Technologist), K.J. Hansen (supervising waste management engineer) and J.G. Hawkins (senior waste management engineer). Computer assistance was provided by S. Leuchter (computer specialist). Report drafting was the responsibility of J.G. Hawkins and A.M. Somani (senior supervising waste management engineer). M.J. Riddle (Assistant Manager, Environmental Division - Western Region) was project manager.

We wish to extend our thanks for assistance provided by the scientific authorities, A. Stelzig and W. Richardson of the Environmental Protection Service at Environment Canada. In addition, the contribution made by those in other federal government departments and the oil and gas industry who reviewed this report is gratefully acknowledged; as is the assistance provided by D. Beaulieu at Environment Canada.

EXECUTIVE SUMMARY

The commercial development of heavy oil and oil sands reserves will proceed in the future as reserves of conventional oil are depleted. This development, however, must be both energy-efficient and environmentally sound. New technologies are being developed and existing technologies modified to ensure that any future plants will be efficient at recovering and upgrading bitumen as well as limiting emissions to the environment. This study provides an extensive data base on gaseous, liquid and solid waste emissions from 15 optional mining oil sands complexes which include a variety of existing technologies as well emerging technologies. The waste management information is suitable for a level of investigation normally associated with the conceptual design stage of a project.

Of the 15 oil sands complexes investigated in this study, ten were sized to produce synthetic crude at 20 000 m^3/d with the remaining five complexes downsized to produce 3000 m^3/d. A variety of unit processes were assembled as building blocks within mining, extraction, upgrading, utilities and offsites to form 15 fully integrated mining oil sands complexes.

The selection of unit processes for this study involved a review of commercially proven processes and of the development status of emerging technologies. In addition, the extent of available waste management information was a factor which was given significant weight in the establishment of the unit process building blocks. Table 1 provides a summary of the processes which form the basis of the 15 selected mining oil sands complexes.

MINING

The oil sands reserve used to compute oil sands feed rate, component sizes and emissions was assumed to be overlain by 23 m of sands, silts and clays and 2 m of muskeg. The thickness of the oil sands reserve was assumed to be 55 m. Oil sands are mined by electric-powered excavation equipment (bucketwheel excavators and draglines with bucketwheel reclaimers) operating on a multiple bench. The oil sands are transported to extraction by conveyors where lower grade ore is blended with higher grade material. The average oil sands feed to the extraction plant was assumed to contain 83.5% solids by weight, 11.5% bitumen by weight and 5.0% water by weight. Further, it was assumed that the bitumen contains 4.9% sulphur by weight.

EXTRACTION

Extraction processes examined in this study included:

1. Hot Water Extraction Process with Tailings Pond,

TABLE 1

Selected Oil Sands Complexes

Option	Production m^3/sd	Extraction	Upgrading	Utilities
1	20000	Hot Water	Fluid Coking	CO Boilers, Coke Boilers
2	20000	Hot Water, Tailings Filtration	Fluid Coking, Gasification of Coke	CO Boilers, Waste Heat Boilers, Medium Joule Gas Boilers
3	20000	Hot Water	Flexicoking	Flexigas Boilers
4	20000	Hot Water	H-Oil	Pitch Boilers, Waste Heat Boilers
5	20000	Hot Water, Tailings Filtration	H-Oil, Partial Oxidation of Pitch	Natural Gas Boilers, Waste Heat Boilers
6	20000	Hot Water	CANMET	Pitch Boilers (FBC), Natural Gas Boilers, Waste Heat Boilers
7	20000	Hot Water	Eureka, Gasification of Pitch	Medium Joule Gas Boilers, Waste Heat Boilers
8	20000	Solvent (Dravo)	Fluid Coking	CO Boilers, Coke Boilers (FBC), Natural Gas Boilers
9	20000	Solvent (Dravo)	Flexicoking	Flexigas Boilers
10	20000	Direct Coking (Lurgi)		Natural Gas Boilers (standby)
11	3000	Hot Water	Fluid Coking	CO Boilers, Coke Boilers
12	3000	Hot Water, Tailings Filtration	H-Oil, Partial Oxidation of Pitch	Natural Gas Boilers, Waste Heat Boilers
13	3000	Hot Water	CANMET	Pitch Boilers (FBC), Natural Gas Boilers, Waste Heat Boilers
14	3000	Solvent (Dravo)	Flexicoking	Flexigas Boilers
15	3000	Direct Coking (Lurgi)		Natural Gas Boilers (standby)

CO	Coke Gas from Fluid Coking
FBC	Fluidized Bed Combustion
sd	Stream Day

2. Hot Water Extraction Process with Tailings Filtration,
3. Dravo Solvent Extraction Process, and
4. Lurgi Ruhrgas Direct Coking Process.

With the operation of Suncor and Syncrude, the Hot Water Extraction Process with tailings pond is the only commercially proven Athabasca oil sands extraction process. The waste solids are discharged from the process in slurry form to a large tailings pond. Water is reclaimed from the tailings pond after a considerable retention time and is reused in the extraction plant.

Hot Water Extraction with tailings filtration combines the commercial experience of the hot water extraction process with a patented pilot plant study on the vacuum filtration of tailings. Vacuum filtration of flocculated tailings generates a low solids filtrate which is recycled to extraction and a filter cake (dry tailings) which is conveyed back to the mine for disposal. Since a tailings pond is not required with this extraction option, wastewaters from the entire complex must be treated in an extensive wastewater treatment system prior to reuse in the plant or discharge to the environment.

The Dravo Solvent Extraction Process utilizes a hydrocarbon solvent to extract the bitumen from oil sands. As reported by the process licensor (Dravo Engineers, Inc.), the process recovers more bitumen from the oil sands than the hot water extraction process. Dry tailings are generated containing 0.5% bitumen by weight and less than 0.1% solvent by weight. Water removed from the oil sands contains trace organics and requires treatment.

The Lurgi Ruhrgas Direct Coking Process utilizes a fine-grained heat carrier for retorting raw oil sands. The heat demand of the system is met by combusting the pyrolysis residues of the process. Primary upgrading is achieved within the process with intermediate liquid products requiring further upgrading (secondary upgrading) into synthetic crude. Waste solids from the process are dry. Sour water from the process contains high levels of phenols and fatty acids, which must be removed prior to reuse.

UPGRADING

Diluted bitumen from extraction is routed through a diluent or solvent recovery process to primary upgrading where the bitumen is upgraded to intermediate product streams using such primary upgrading processes as Fluid Coking, Flexicoking, H-Oil, CANMET and Eureka. The products of primary upgrading, naphtha, gas oil and distillate, are subject to further treatment in separate hydrotreaters (secondary upgrading) and diluent or solvent make-up requirements for extraction are obtained from the secondary upgrading products. The products of secondary upgrading are then blended as synthetic crude. Product sour gases are recovered from primary and secondary upgrading and stripped of H_2S in the amine plant. Resultant sweet process gas is utilized in the upgrading and utilities processes.

Primary upgrading processes examined in the study include the carbon rejection technologies of the Fluid Coking, Flexicoking and Eureka processes, and hydrogen addition technologies of the H-Oil and CANMET hydrocracking processes. For each of these processes, waste streams were identified from available literature sources and rates were computed from published or estimated conversion efficiencies to produce 20 000 or 3000 m^3/d of synthetic crude.

Processes which are also included in the upgrading area of the plant are the sulphur plant, sour water stripper and hydrogen plant. Within the sulphur plant, H_2S-rich gases from primary upgrading and other unit processes in the upgrading area are thermally and catalytically converted to elemental sulphur in Claus sulphur recovery units. Tail gases are cleaned up in Shell Claus Off-Gas Treating units with resultant off-gases incinerated before venting to the atmosphere. Wastewater from various unit processes is stripped of H_2S and NH_3 in the sour water stripper. The hydrogen requirements of upgrading are provided by steam reformation of natural gas and process gas. In three of the selected options, a portion of the hydrogen is supplied by the partial oxidation of residues from primary upgrading.

All primary upgrading processes included in the study produce high sulphur residues. Since utilization of residues is likely to form n integral part of future oil sands complexes, various options for residue utilization were examined in this study. These included residue fired utility boilers for steam production, gasifying residues to produce a medium joule fuel gas for subsequent use in utilities and utilizing residues for the production of hydrogen for use in the hydrogen addition primary upgrading processes.

UTILITIES

Steam, electricity and high quality water required in the complex are supplied from the utility area. For the purposes of this study, it was assumed that the raw water supply for the complex is the Athabasca River. Boiler feedwater is treated by warm lime softening, filtration and demineralization.

A variety of steam raising methods were examined from a waste management standpoint. These included CO boilers, coke or pitch fired boilers (both conventional-type and fluidized bed) and gas fired boilers using as fuels, natural gas, process gas, low joule fuel gas from Flexicoking and medium joule fuel gas from coke or pitch gasification. The overall plant objective of 3.2 tonnes of SO_2 per 1000 m^3 of bitumen feed to upgrading was applied to the calculated emissions from the CO, coke and pitch fired boilers to determine the degree of desulphurization required. Emissions were then corrected to reflect the SO_2 reduction as well as particulate removal from the flue gases. It was assumed that the power requirements of the complexes were generated by back pressure and steam turbines and/or gas turbines. Where gas turbines were included in the utility plant of the selected options, waste heat was recovered in waste heat boilers.

Cooling towers are also located in the utility area and it was assumed that four cycle cooling was achieved in the system.

OFFSITES

Operations which are supportive to the oil sands processing units are often neglected when analysing emissions, however, they contribute significantly to land use requirements and overall plant emissions. Facilities such as potable water treatment, sewage treatment, water and wastewater collection and conveyance systems, treatment systems for process wastewater, offices, cafeterias, accommodation units, on-site pipelines, roadways and parking areas are common to all mining, extraction, upgrading and utilities alternatives. As well, sulphur storage and load-out facilities, the plant flare system, bitumen tankage and residue storage areas are included in the offsites area.

DATA ASSEMBLY AND PRESENTATION

For each of the major unit processes and supportive operations and processes within mining, extraction, upgrading, utilities and offsites, the gaseous, liquid and solid waste streams were identified. In order to quantify these emissions, bitumen recovery and conversion efficiencies of extraction and upgrading were obtained from literature sources and were applied to the synthetic crude production rates established for this study (20 000 and 3000 m^3/d). Waste stream flow rates were then prorated from reported rates in the literature or from rates obtained directly from process licensors.

Emissions characterization data for each unit process was assembled from a variety of sources which include:

1. published information,
2. communication with process licensors,
3. analyses of similar unit processes,
4. calculations, and
5. in-house data.

Apart from waste stream characterization data from the hot water extraction process, very little operational emissions data is included directly in the data base. Waste management information from the existing oil sands plants consists primarily of liquid effluents combined from several unit processes. Hence, this information could not be applied directly to this study.

The waste management data base is not to be considered complete as there are significant gaps in the areas of characterizing trace elements and trace organics. In addition, the constituents of the total organics in liquid and solid waste streams are not identified. These gaps are attributed to the secondary importance given to the gathering of waste management data in laboratory studies and in pilot and full scale plant analysis.

Waste stream characterization data for each unit process are stored in a computerized data storage, manipulation and retrieval system. Once the data was finalized, it was transferred electronically to pre-drawn waste management matrices and pollutant flow diagrams utilizing a computer aided drafting and design system. For each of the selected options, all gaseous, liquid and solid waste streams were identified and characterized on waste management matrices. Summaries of all waste streams from the unit processes within the selected options are displayed on the pollutant flow diagrams. The diagrams also illustrate the conceptual waste collection and distribution network, total stream day and total annual flows in each network and the waste management scheme established for each option.

WASTE MANAGEMENT

For each of the selected options, the waste management data base was used to establish a conceptual waste collection and distribution network, wastewater treatment scheme and flue gas treatment requirements. The waste collection and distribution network, which is displayed on pollutant flow diagrams, conveys liquid or solid waste streams of similar quality to required treatment components or disposal systems. Wastewater treatment components were selected and sized on the basis of the waste management data to produce an effluent suitable for reuse within the plant or for discharge to the environment.

In terms of flue gas treatment, the overall objective of 3.2 tonnes SO_2 per 1000 m^3 of bitumen feed to upgrading was used to derive the flue gas desulphurization (FGD) required for CO boilers (fluid coking) and residue fired boilers. The ammonia scrubbing system for flue gas desulphurization was identified as a candidate system and was applied to the boiler flue gases which required sulphur removal. This system generates a liquid byproduct containing ammonia sulphite and ammonia bisulphite in the range of 250 to 400 g/L (as bisulphite). Disposal options for the FGD byproduct are as a direct application fertilizer or as a feedstock to the fertilizer industry. For three of the selected options, fluidized bed boilers with limestone addition for desulphurization were examined. The product of desulphurization within the fluidized bed ($CaSO_4$) is removed as spent bed material and disposed of by landfilling in the mined-out area of the oil sands mining operation. For each of the CO boilers and residue fired boilers, reduction of particulate emissions is achieved with electrostatic precipitators.

A sulphur balance and water balance for each of the selected oil sands complexes were computed to illustrate the disposition of these materials. Maximum recycle of treated wastewater within the oil sands complexes was assumed for such uses as make-up to the extraction plant, make-up to product gas scrubbing systems, make-up to flue gas scrubbing systems, water supply to clean-up and washdown systems, make-up to slurrying and sluicing systems, and possibly, make-up to the cooling water system. A detailed chemical balance is required to confirm the disposition of recycled water over the long-term.

Solid wastes from mining, extraction, upgrading, utilities and offsites are transported by conveyors and trucks to the mine for disposal by landfilling in the mined-out area. These waste materials include overburden from the mining operation; rejects and dry tailings from extraction; char, slag, coke fines and possibly spent catalysts from upgrading; and fly ash, bottom ash, spent bed material and incinerator ash from utilities and offsites. Concerns with respect to the landfilling of these materials primarily relate to the leaching and migration of metals.

Order-of-magnitude cost estimates were prepared for the waste treatment systems for each of the selected oil sands complexes. Capital costs for wastewater treatment are very dependent on the presence of a tailings pond and, for those complexes producing 20000 m^3/d of synthetic crude, range from approximately $25 million for the options with a tailings pond to about $93 million for the direct coking option. As expected, there are considerable economies of scale associated with the wastewater treatment system. For the smaller scale complexes producing 3000 m^3/d of synthetic crude, capital costs for wastewater treatment are in the order of 40% of costs for similar larger scale complexes producing 20 000 m^3/d.

SATELLITE PLANT ANALYSIS

Satellite mining operations providing oil sands to a centralized extraction and upgrading plant, and satellite mining and extraction facilities providing bitumen feed to a centralized upgrader were examined from a waste management standpoint. The management of tailings is a major problem identified in the option of satellite mining operations. If tailings are wet, it would be impractical to convey tailings back to the satellite mines for disposal with in-pit tailings ponds, hence, a large external tailings pond would be required at the central extraction plant. On a similar basis, the large volumes of waste solids from those extraction processes generating dry tailings may preclude conveyance back to the satellite mines for disposal, and stockpiling of the material may be required.

With respect to the option of satellite mining and extraction operations providing diluted bitumen to a central upgrader, the opportunities for reuse of waste heat and recycling of residues and wastewater are lost because of the difficulty and costs associated with moving these surpluses. Accordingly, there would be duplication of utilities and waste treatment facilities at the satellite plants and centralized upgrader. As a result, there would be an overall increase in gaseous, liquid and solid waste emissions.

CONCLUSIONS

The conclusions of this study are provided as follows:

1. A review of the waste management data in this report indicates that there are significant data gaps, particularly in the emissions characterization data. Characterization information is very limited for trace elements and organic compounds in gaseous, liquid and solid waste emissions. Data collected from operating processes, either at the full or pilot scale, have been mainly oriented toward process performance. Characterization of emissions has tended to be of secondary concern. The exceptions are those pollutants which are or will be controlled by government requirements (e.g. SO_2, NO_x, phenol, etc.). In these cases, the emissions data base is somewhat more complete.

2. As required by the study terms of reference, waste management data in this report relate to mining oil sands processes operating under normal conditions. However, from a waste management standpoint, analysis of plant operations during upset conditions is critical because it is during upset conditions that liquid, gaseous and solid waste emissions are frequently at their maximum levels, putting waste handling and treatment facilities under maximum load conditions. Therefore, regulatory agency concerns are frequently associated with emissions under plant upset conditions. In light of the incomplete waste management data base, for processes under normal operating conditions, as identified above, it is believed that there is little or no relevant data for mining oil sands processes under upset conditions.

3. The increased utilization of solid residues from the primary upgrading processes is limited by the lack of demonstrated technology, particularly in the areas of coke or pitch gasification and steam raising using conventional boilers or fluidized bed boilers.

4. Operating experience for flue gas treatment under the severe operating conditions resulting from the utilization of by-product coke or pitch in conventional boilers is very limited.

5. As identified previously, there is a lack of wastewater characterization data and this is coupled with insufficient information on the treatability of these wastewaters. This is particularly the case for

processes currently at the pilot scale, for example, direct coking and solvent extraction processes, and CANMET and Eureka upgrading processes.

6. The wastewater treatment system for the sour water from the Lurgi Ruhrgas Direct Coking Process has been established on the basis of limited data. There are concerns with respect to the treatment and disposal or recovery of the fatty acids. The wastewater treatment system established for this waste stream, and subsequent costs should be viewed as very preliminary. For practical reasons, alternative treatment/recovery methods are required, but must be analyzed with the benefit of complete wastewater characterization data.

7. A review of the pollutant flow diagrams indicates the extensive nature of the wastewater treatment systems for those options without a tailings pond. It is our belief that, while there is demonstrated treatment technology suitable to treat these wastewaters for either reuse or direct discharge, the size and scale of the treatment systems coupled with the lack of emissions data for process upset conditions will create numerous design, construction and operational problems.

8. All the options considered in this study rely on water recycle or reuse to a certain extent. Information on acceptable water quality for recycle or reuse in a process area is incomplete at best. Further, the long-term implications of wastewater recycle and reuse on overall process water quality have not been examined.

9. Comparison of costs for wastewater treatment between tailings pond options, tailings filtration options, solvent extraction options and direct coking options may not be applicable since some of the processes include pretreatment of wastes. Also, as identified above, the costs for the direct coking options are very sensitive to the identification of the fatty acid component of the direct coking sour water. In general, it can be concluded that for similar capacity oil sands complexes, the costs for wastewater treatment systems for tailings pond options (1, 3, 4, 6, 7, 11 and 13) are approximately 50% of the treatment costs for tailings filtration options (2, 5 and 12) and solvent extraction options (8, 9 and 14). The treatment costs for options with tailings filtration and solvent extraction range between \$44 x 10^6 to \$54 x 10^6 for 20 000 m^3/d capacity complexes with costs for solvent extraction options tending towards the higher figure because of greater wastewater flows.

10. There are considerable economies of scale associated with the capital cost of wastewater treatment facilities. The synthetic crude production rate for the smaller oil sands complexes is 15% of the rate for the larger complexes, however, the capital costs for wastewater treatment are in the order of 40% of the costs for the larger complexes, providing similar levels of treatment in each case.

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PART 1

INTRODUCTION

PART 1 - INTRODUCTION

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1.1 INTRODUCTION

As reserves of conventional oil are being depleted, the commercial development of reserves of heavy oil and oil sands is becoming increasingly important. The largest reserves in Canada are located around the Athabasca, Peace River and Cold Lake areas of Alberta and Saskatchewan. The reserves are thought to approximate one trillion barrels of which only a fraction is recoverable with present technology.

Oil (or bitumen) extracted from oil sands and heavy oil, which has an API varying from 3.7 to 15, cannot be recovered using conventional production techniques. Currently, recovery is either by mining the oil sands deposits located near the surface or by in situ thermal stimulation techniques for heavy oil reserves located at greater depths. Once the bitumen has been extracted from the oil sands, it is upgraded to synthetic crude by a variety of primary and secondary upgrading techniques. Synthetic crude is normally pipelined to a refinery for additional processing into required products.

The constituent parts of a mining oil sands complex are:

- surface mining operations;
- extraction processes;
- primary and secondary upgrading; and
- associated utilities and offsites.

Environmental problems associated with a mining oil sands complex are related to gaseous, liquid and solid waste emissions from the various processes outlined above.

Attempts to minimize the environmental impact of a mining oil sands complex centre around either treating any emissions prior to discharge (or venting) or, alternatively, utilizing proven technologies which minimize the production of emissions. Environmental regulatory agencies will be pressing future oil sands developments to either:

1. significantly reduce emissions by extensive and costly treatment, or

2. adopt technologies that have a reduced environmental impact over those currently in commercial use.

It is, however, incumbent on both the oil and gas industry and the regulatory agencies to thoroughly evaluate all the alternative process and treatment options for reducing the environmental impact of such oil sands developments. This is particularly the case when evaluating new and alternative process and treatment technologies which could, in the long run, be more costly and less reliable than those currently proven as commercially viable.

1.2 STUDY OBJECTIVES

The major objective of this study is to provide information on the characteristics of gaseous, liquid and solid waste emissions and their required treatment for a variety of possible mining, extraction, upgrading and utility process options associated with a mining oil sands complex. The process options considered in this report are those which are commercially proven for handling Athabasca oil sands and bitumen or which show commercial promise. Waste management information is specifically provided for different process configurations making up 15 different oil sands complexes, ten producing 20 000 m^3/d of synthetic crude and five producing 3000 m^3/d of synthetic crude. Information on the handling and required treatment of gaseous, liquid and solid waste emissions for each of the 15 complexes (options) is also provided, together with associated treatment costs.

For each of the 15 complexes (options), the following is also provided:

- summary of conversion efficiency from oil sands to synthetic crude;
- sulphur balance; and
- water balance.

Finally, the report discusses the waste management implications of satellite plant facilities such as a number of small mines and extraction facilities providing bitumen feed to a large centralized upgrader.

1.3 REPORT FORMAT

The process and waste management information contained in this report was obtained from the following sources:

- detailed review of the available literature;
- in-house information;
- calculations and mass balances based on materials composition; and
- licensor information.

A number of assumptions have been made to assist in data handling and manipulation and these assumptions are detailed in the text of this report. In addition, it should be noted that there are significant information gaps, particularly in the waste management data base associated with process technologies which are not commercially proven for the extraction and upgrading of Athabasca oil sands and bitumen (emerging technologies). In light of these assumptions and gaps in the process and waste management data base, caution must be exercised in using or interpreting the data for situations other than outlined in this report. It is believed that the information contained in this report is generally suitable for a level of investigation normally associated with the conceptual design stage of a project.

This report is broken down into nine parts as follows:

Part 1 - Introduction

- study description, terms of reference and application of data.

Part 2 - Process Selection

- identification of alternative processes for mining, extraction and utilities;
- brief description of selected mining, extraction, upgrading, utilities and offsites processes;
- outline of the rationale used to select processes for the 15 complete mining oil sands complexes (options); and
- brief description of the 15 options.

Part 3 - Waste Stream Identification and Characterization

- identification and brief description, with assumptions, of each waste stream for each process in mining, extraction, upgrading, utilities and offsites; and
- presentation of waste management information for each option using pollutant flow diagrams and waste management matrices.

Part 4 - Waste Management

- identification of regulatory requirements associated with a mining oil sands complex;
- quantification of residuals and byproducts and their possible recycle and reuse;
- description of wastewater and solid waste collection and transportation systems;
- discussion of flue gas treatment systems for SO_2 and particulate removal;
- description of wastewater treatment schemes for each option;
- identification of solid waste disposal methods; and
- discussion of long-term waste management ramifications.

Part 5 - Material Balances

- summary of the efficiency of conversion from oil sands to synthetic crude for each option;
- sulphur balance for each option; and
- water balance for each option.

Part 6 - Cost Estimates

- identification of basis for the cost estimates; and
- cost estimates for wastewater and flue gas treatment and solid waste disposal for each option.

Part 7 - Satellite Plant Analysis

- review of waste management implications of satellite plant operations.

Part 8 - Conclusions and Recommendations

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PART 2

PROCESS SELECTION

PART 2 - PROCESS SELECTION

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FIGURES (Cont'd)

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2.1 INTRODUCTION

The oil sands of the Athabasca area contain varying quantities of bitumen and fine solids which have a direct impact on the effectiveness and economics of extracting the bitumen from the oil sands. The viscous, high sulphur, high nitrogen, high metals bitumen then must be upgraded to distillable fractions which are further processed by hydrotreating. The products of this primary and secondary upgrading, blended together as synthetic crude, are transported by pipeline and processed into fuels by conventional refineries.

The selection of mining techniques, processes for extraction and upgrading and methods for producing required steam, power and water involves an exhaustive technical and economic analysis of performance factors. While this level of analysis is beyond the scope of this study, the selection of unit processes as building blocks for the assembly of the 15 options has involved a review of commercially proven processes and of the development status of emerging technologies. The nature of available waste management information is a factor which has been given significant weight in the selection of the unit process building blocks.

Mining of oil sands and subsequent extraction and upgrading of bitumen requires significant quantities of electricity, steam and water. While existing oil sands complexes rely on imported hydrocarbons (Suncor does burn pulverized coke from primary upgrading in utility boilers), future oil sands complexes will have to be energy efficient in terms of recovery of bitumen and utilization of residues. Accordingly, residues from primary upgrading will be utilized as fuels in utility boilers, or alternatively gasified to a fuel gas which then may be used in utility boilers, or in the manufacture of hydrogen. Since residues from primary upgrading are high-sulphur fuels, utility boilers require effective flue gas desulphurization units to reduce sulphur emissions to levels acceptable to regulatory agencies. In this study, various alternatives for the utilization of residues are examined and expected emissions are characterized.

Mining methods are a function of site-specific factors, performance of excavating equipment and economics. Since waste emissions from mining are not significantly affected by variations in the mining method, a common mining technique is assumed for all selected options.

In this study, major process units required for the recovery of hydrocarbons from oil sands are categorized into five separate areas: mining, extraction, upgrading, utilities and offsites. This method of categorization of processing units is common to the industry and is carried throughout the various aspects of this study.

In Part 2, the alternative processes which are proven or under development are introduced in Section 2.2, Mining; Section 2.3, Extraction; Section 2.4, Upgrading; and Section 2.5, Utilities. The operations which are supportive to the major process units are summarized in Section 2.6, Offsites. The 15 selected options include those unit processes with proven commercial operation and emerging technologies which are being considered as alternatives to existing technology. These are described in detail in Section 2.7, Selected Oil Sands Complexes.

2.2 MINING

Operations within mining include site preparation, dewatering, muskeg stripping, subsoil excavation and oil sands mining. Methods utilized within mining operations are a function of many site specific factors including the nature of the surface of the lease, the thickness of overburden, thickness and quality of the oil sands reserve, hydrogeological conditions and, of course, performance and capacity of large excavating equipment.

Vegetation in the Athabasca oil sands area is a mixture of deciduous and coniferous trees. As a large portion of the area is covered by poorly drained muskeg, stunted black spruce occur in clumps with small islands of jack pine and white spruce. The organic soils are generally treeless, however, in areas with improved drainage, tree cover improves with aspen poplar dominating (Carrigy 1973). Site preparation of the mining area involves the removal of the vegetative cover and excavation of an extensive network of drainage ditches which are undertaken a few years in advance of the mining operation. Drainage of the surface area is required to permit stripping of the muskeg.

Muskeg is stripped from the area during the winter months since the moisture content of the organic soils remains high. Generally, large front-end loaders, supplemented with bulldozers equipped with rippers, are utilized for muskeg stripping. Muskeg is transported by large capacity trucks to dyked stockpiles or to the mined-out area where it is incorporated into the mine reclamation program.

It may be necessary to depressurize artesian water bearing zones in the area to minimize seepage into the active mining area. This could be accomplished where required by active or passive systems, the method being a function of depth, pressures and other hydrogeologic factors. An active system would involve pumping of groundwater from a series of wells, whereas passive systems include placement of standpipes and collection and pumping of water from the base of the mine (Alsands Project Group 1978).

A number of possible variations may be utilized for excavating subsoil and mining oil sands. Existing oil sands mines utilize large electric bucketwheel excavators which feed the excavated material directly to conveyors, and large electric draglines which excavate and stockpile subsoil or oil sands. Bucketwheel reclaimers are then required to transfer the stockpiled materials to conveyors or vehicles. The excavating equipment could be operated on a single level or bench, or on multiple benches. The mining method would be established after a detailed analysis of site-specific factors, equipment capability, and economics. Aside from the ability of draglines to selectively mine interbedded waste materials, no significant variation in emissions with mining methods appears to exist.

2.3 EXTRACTION

The Hot Water Extraction Process for the extraction of bitumen from Athabasca oil sands is currently the only commercially proven extraction method. Hot water extraction followed by froth treatment is the method used at the two existing oil sands plants (Suncor and Syncrude). As well, hot water extraction was proposed for Alsands. The process is sensitive to the raw oil sands quality and its shortcomings are related to the nature of the waste solids from the extraction process. Two tailings streams are generated in hot water extraction and froth treatment and are pumped as slurries to a large tailings pond. The tailings are a mixture of fine-grained sand and water with dispersed silt, clay and bitumen. Within the tailings pond, sand and a portion of the fines settle rapidly with a layer of water suitable for recycle to the extraction plant established at the surface. The silt and clay, and most of the bitumen, remain in suspension within the central layer as a sludge. Sedimentation and consolidation of this sludge occurs slowly, necessitating large tailings ponds. In addition, there are long-term environmental concerns associated with reclamation and abandonment of the ponds.

Alternative extraction technologies are being developed at the laboratory and pilot scale. However, none of the technologies have been demonstrated at sufficient scale to allow their use commercially. Alternative processes include direct coking, solvent extraction and other aqueous extraction methods.

231 DIRECT COKING

Direct coking of raw oil sands involves heating the oil sands such that thermal cracking and distillation occurs. Vapour products from thermal cracking are subsequently condensed to form intermediate liquid products for secondary upgrading (hydrotreating). A coke deposit is retained on the sand and this is combusted within the direct coking unit to provide process heat.

The process is not as sensitive to oil sands bitumen quality as other extraction processes. Waste solids from the process are dry, thus eliminating the large tailings pond. Primary upgrading of the intermediate products is not required since some degree of upgrading is achieved in the process. Intermediate products from direct coking are further upgraded in hydrotreaters.

Direct coking processes at the development stage include:

1. Taciuk Direct Thermal Processor developed by UMATAC Industrial Processes Ltd.
2. Lurgi-Ruhrgas Direct Coking Process developed by Lurgi GmbH and Ruhrgas AG in West Germany.
3. Anhydrous Extraction Process developed by the University of Calgary (presently at the conceptual stage).

While a tailings pond is not required in the direct coking processes and water requirements are substantially less than hot water extraction, an extensive wastewater treatment system is required for all process wastewater. Further, sour water from the direct coking process has a high phenol content, and if treated biologically prior to reuse, generates significant volumes of biological sludge for disposal.

232 SOLVENT EXTRACTION

Extraction of bitumen from oil sands utilizing various solvents has received considerable interest. Various supercritical solvents and other conventional hydrocarbons such as naphtha have been used. Solvent losses from the processes are a concern and the reduction of solvent losses has required the development of innovative recovery techniques. Waste solids from solvent extraction are dry, hence, a tailings pond is not required. As a result, an extensive wastewater treatment system is required to treat interstitial water removed from the oil sands in the extraction process as well as other wastewaters from upgrading, utilities and offsites.

Solvent extraction processes which are currently at the pilot stage of development include:

1. Solvent Extraction - Spherical Agglomeration Process developed by the National Research Council of Canada.
2. Dravo Solvent Extraction Process developed by the Dravo Corporation.
3. Magna Oil Sands Extraction Process (cold water and solvent) developed by Magna International and the National Research Council of Canada.

233 AQUEOUS PROCESSES

Studies of the hot water extraction process have led to modifications which increase bitumen yields and reduce or eliminate the necessity of the large tailings pond. Processes which are at various stages of development include:

1. Two Stage Extraction (Cymbalisty 1980)
2. RTR Process (Houlihan 1982)
3. Kruyer Process developed by Kruyer Research and Development Ltd.

In addition to the above, a number of laboratory studies have been undertaken directed at enhancing the sedimentation and consolidation rate of the sludge layer in tailings ponds. If successfully applied, enhanced settling and consolidation of fines would have the effect of reducing the size of tailings ponds and permitting increased water recycle to the hot water extraction process.

Dewatering of tailings generated from hot water extraction and froth treatment has received some attention, however, the currently available literature on the subject is limited. Liu et al (1980), in a patented study on treatment of whole tailings by flocculation and vacuum filtration, successfully dewatered whole tailings to produce a filtrate suitable for recycle to the hot water extraction process and tailings with a moderate moisture content which may be disposed of as a solid. Considerable further development work is required on tailings filtration to demonstrate commercial application. Whole tailings treatment, based on electrophoresis and reverse osmosis of chemically conditioned tailings slurries (Ritter 1981) has been developed on a bench scale. Verification of process details is required at a larger scale.

2.4 UPGRADING

Primary upgrading of bitumen at the two existing oil sands complexes is accomplished by coking, a carbon rejection technique. Delayed coking (Suncor) and Fluid Coking (Syncrude) are conventional methods for primary upgrading. Fluid Coking and Flexicoking were proposed for primary upgrading of bitumen and heavy oil respectively in the proposed Alsands and Cold Lake facilities. All of these carbon rejection processes generate a high sulphur coke byproduct. In the Flexicoking process, the coke produced is gasified to produce a low joule fuel gas.

Another carbon rejection process which is under development in Japan is the Eureka process (Aiba et al 1982) . Similar to delayed coking, the process utilizes superheated steam to prevent coke formation and increase liquid yields.

Hydrogen addition processes, an alternative to the conventional carbon rejection processes, are considered to be emerging technologies for the primary upgrading of bitumen. Catalytic hydrocracking processes such as H-Oil, licensed by Hydrocarbon Research Inc. and Texaco Development Corporation, and LC-Fining, licensed by CE Lummus Co. and Cities Service Research and Development Co. are similar processes for upgrading heavy, high sulphur, high metals residual fractions (Rubero and Balakrishnan 1982). The CANMET process, developed by the Federal Department of Energy, Mines and Resources, is a non-catalytic process which utilizes hydrogen and a coal additive in the upgrading reactor (Menzies et al 1981). For the hydrogen addition processes, higher liquid yields have been achieved in pilot plants than yields from carbon rejection processes.

The products from primary upgrading are unstable intermediates which require further treatment in secondary upgrading. Similarly, the intermediate products from direct coking are further upgraded in secondary upgrading. This is undertaken in hydrotreaters where hydrogenation occurs and additional nitrogen and sulphur are removed from the intermediate products. The liquid products from secondary upgrading are then blended as synthetic crude and transported by pipeline to conventional refineries.

Other unit processes which are included in the upgrading area are gas recovery units, amine plant, sulphur plant, sour water stripper and hydrogen plant. These are all conventional processes which are common to all of the aforementioned upgrading alternatives. Other unit processes such as residue gasification units for conversion of coke or pitch residues to medium joule fuel gas and related oxygen plants are also included in the upgrading area and are a function of the method of utilization of residues from primary upgrading.

2.5 UTILITIES

Steam and power required in mining, extraction and utilities may be generated by a variety of conventional fuels. The residual by-products of primary upgrading (coke or pitch) are a possible fuel source for utility boilers, however, further development work is required in this area. As well, desulphurization of the flue gas from the residue-fired boilers requires demonstration.

For the purposes of this study, coke and pitch utility boilers are included as unit processes within utilities recognizing that demonstration units are required to determine overall feasibility. It is assumed that residue-fired boilers, either fluidized bed or conventional-type with flue gas desulphurization, will be an alternative residue management scheme in future oil sands complexes.

High quality water requirements such as boiler feedwater are produced in the water treatment plant located within the utilities area. As well, the cooling water requirements of extraction and upgrading are provided by utilities with cooling towers and required make-up, treatment and blowdown facilities.

2.6 OFFSITES

Operations which occur outside of the battery limits of mining, upgrading and utilities are included in the offsites area. These operations, which are supportive to the oil sands processing units, are often neglected when analyzing emissions, however, they contribute significantly to land use and emissions. Facilities such as potable water treatment, sewage treatment, water and wastewater collection and conveyance systems, treatment systems for process wastewater, offices, cafeterias, accommodation units, on-site pipelines, roadways and parking areas are common to all mining, extraction, upgrading and utilities alternatives. As well, sulphur storage and load-out facilities, the plant flare system, bitumen tankage, and residue storage areas are included in the offsites area.

2.7 SELECTED OIL SANDS COMPLEXES

The selection of optional processes for detailed examination in this study has involved a review of the development or performance status of extraction and upgrading technologies, the nature of available waste management information and the objective of presenting waste emissions and treatment requirements for alternative processes which do not require a large tailings pond. Table 2-1 identifies the major unit processes within extraction, upgrading and utilities which have been assembled to form 15 complete mining oil sand complexes. A common mining method is established for all options. In all of the selected options, maximum utilization of residuals in utility boilers, in hydrogen production or medium joule fuel gas production has been applied.

The 15 selected options represent complete and apparently viable options for the mining, extraction and upgrading of Athabasca oil sands and utilization of byproducts. With the possible exception of vacuum filtration of whole tailings as a tailings dewatering technique and the utilization of coke or pitch residues, all of the unit processes selected have been applied to oil sands at full scale or pilot facilities.

TABLE 2-1

Selected Oil Sands Complexes

Option	Production m^3/sd	Extraction	Upgrading	Utilities
1	20000	Hot Water	Fluid Coking	CO Boilers, Coke Boilers
2	20000	Hot Water, Tailings Filtration	Fluid Coking, Gasification of Coke	CO Boilers, Waste Heat Boilers, Medium Joule Gas Boilers
3	20000	Hot Water	Flexicoking	Flexigas Boilers
4	20000	Hot Water	H-Oil	Pitch Boilers, Waste Heat Boilers
5	20000	Hot Water, Tailings Filtration	H-Oil, Partial Oxidation of Pitch	Natural Gas Boilers, Waste Heat Boilers
6	20000	Hot Water	CANMET	Pitch Boilers (FBC), Natural Gas Boilers, Waste Heat Boilers
7	20000	Hot Water	Eureka, Gasification of Pitch	Medium Joule Gas Boilers, Waste Heat Boilers
8	20000	Solvent (Dravo)	Fluid Coking	CO Boilers, Coke Boilers (FBC), Natural Gas Boilers
9	20000	Solvent (Dravo)	Flexicoking	Flexigas Boilers
10	20000	Direct Coking (Lurgi)		Natural Gas Boilers (standby)
11	3000	Hot Water	Fluid Coking	CO Boilers, Coke Boilers
12	3000	Hot Water, Tailings Filtration	H-Oil, Partial Oxidation of Pitch	Natural Gas Boilers, Waste Heat Boilers
13	3000	Hot Water	CANMET	Pitch Boilers (FBC), Natural Gas Boilers, Waste Heat Boilers
14	3000	Solvent (Dravo)	Flexicoking	Flexigas Boilers
15	3000	Direct Coking (Lurgi)		Natural Gas Boilers (standby)

CO	Coke Gas from Fluid Coking
FBC	Fluidized Bed Combustion
sd	Stream Day

Synthetic crude production rates for 15 selected mining oil sand complexes have been established to be representative of the large scale plants which have been constructed or proposed (Syncrude, Alsands, Canstar), and smaller scale facilities which are currently being considered. Options 1 to 10 are large complexes with a stream day synthetic crude production of 20 000 m^3/day. Options 11 to 15 are scaled down versions of large complexes, with stream day synthetic crude production of 3000 m^3/d.

This section identifies the major extraction and upgrading processes examined in this study, and provides an overall description and block flow diagram for each selected option.

271 MINING

Optional mining equipment and methods such as draglines versus bucketwheel excavators, or single bench mining versus multiple bench mining can only be reviewed on the basis of site-specific factors and economics. The nature and quantities of emissions from mining, however, are not significantly dependent on the mining technique. For the purposes of this study, the average stratigraphic cross-section of the oil sands reserves has been assumed to be as follows:

2m	muskeg
23 m	overburden (subsoil)
55 m	oil sands

For all options, muskeg is stripped during the winter months by diesel-powered equipment and is transported to storage by large trucks. The subsoil is excavated by bucketwheel excavators (electric) and is transported from the area by large trucks. The subsoil is utilized for the construction of dykes or is deposited in the mined-out area as part of the mine reclamation program. Reclamation of the mine is a continuous program which extends over the life of the mine and involves the selective disposal in the mined-out area of subsoil, muskeg, tailings and other solid waste material from oil sands processing. Ultimately, a vegetative cover is established on the reclaimed area.

Oil sands are mined on a multiple bench by bucketwheel excavators and draglines with bucketwheel reclaimers. The excavators and reclaimers load the oil sands on conveyors for transport to the extraction plant surge storage area. Oil sands are subsequently fed from surge storage to the extraction plant by a series of feed hoppers and transfer chutes which load underground conveyors. Since the mined oil sands will be of varying bitumen content, multiple feed hoppers permit blending of lower grade ore with higher grade material, thus providing a consistent oil sands feed quality to extraction. In commerical plants, however, blending of oil sands to achieve consistent extraction plant feed quality has had limited success. For this study it is assumed that the average oil sands feed to extraction contains 83.5% solids by weight (sands, silts and clays), 11.5% bitumen by weight, and 5.0% water by weight.

Emissions from the mining operation include the waste solids from overburden removal, runoff from stockpiles, mine water, discharges from site preparation and dewatering programs, and atmospheric emissions from diesel-powered excavation and transport equipment. As well, dust emissions will periodically occur from excavation operations, from conveyors and vehicular movements, and from stockpiles. Emissions are described in detail in Part 3.

272 EXTRACTION

.1 Hot Water Extraction and Froth Treatment

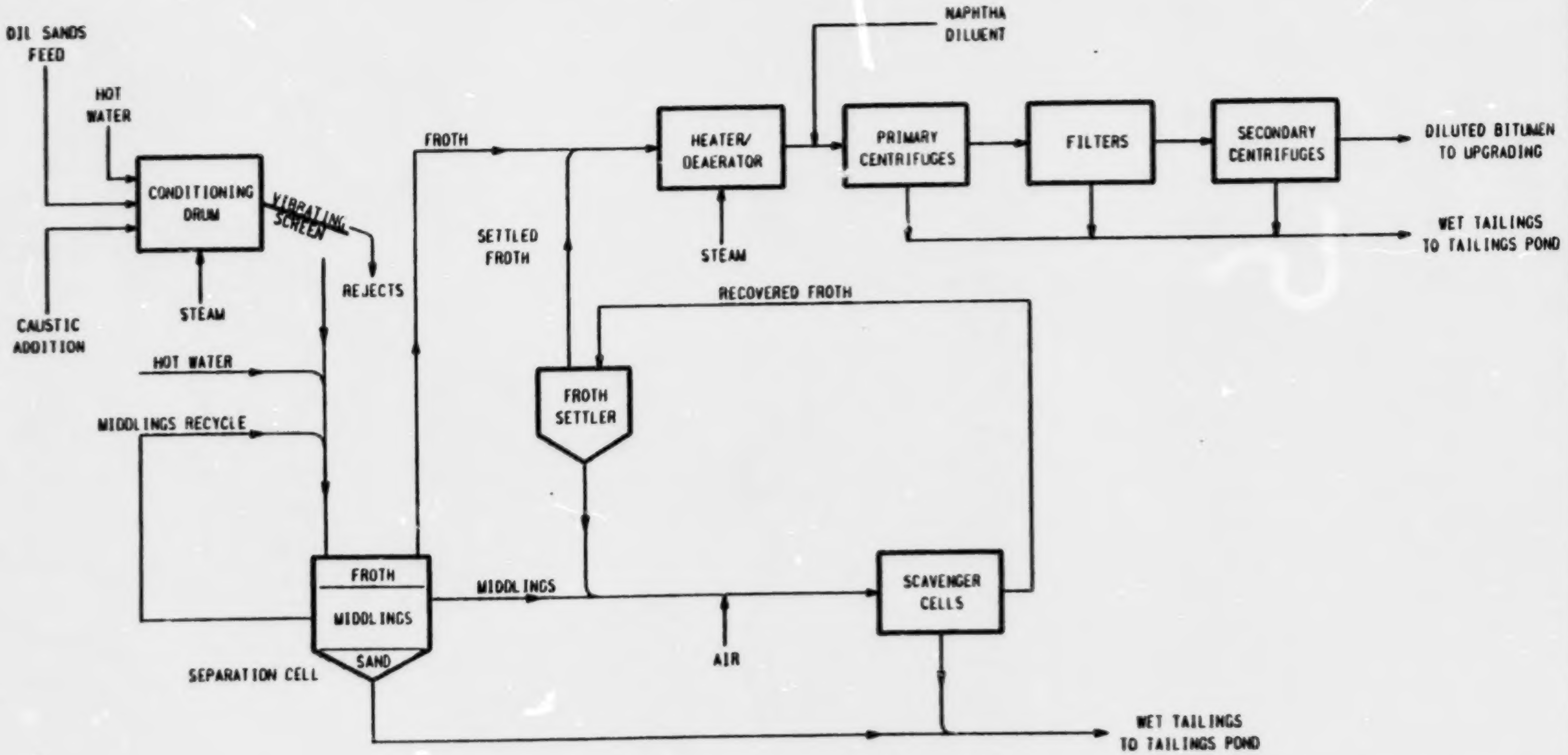
Extraction of bitumen from oil sands by the K.A. Clark Hot Water Extraction Process, with recent technological improvements represents proven full scale technology with the operation of Suncor and Syncrude. Hot water extraction with subsequent treatment of recovered froth is shown in Figure 2-1.

Oil sands are fed to the conditioning drums via conveyors where hot water, steam and caustic are added. The mixture is agitated in rotary drums and the conditioned oil sands pulp is screened for the removal of oversized clay lumps and rocks (rejects). The pulp is then further diluted with additional hot water and a recycle middlings stream prior to introduction to the separation cells.

Within the separation cells, sand particles are removed from the bottom, and a bitumen-rich froth layer is skimmed from the surface. In the central layer known as middlings, significant quantities of bitumen are contained within fine silt and clay particles. The dilute middlings stream is withdrawn from the central layer of the separation cells and is routed to scavenger cells for further bitumen recovery.

Air flotation is utilized in the scavenger cells to produce a scavenger froth which is then settled. Bitumen-rich froth from the froth settlers is combined with the froth skimmed from the separation cells as feed to froth treatment.

Water and fines are removed from the bitumen-rich froth by dilution centrifuging. The froth is heated, deaerated and diluted prior to centrifuging. Naphtha, recycled from upgrading, is used as the diluent which reduces the specific gravity and viscosity of froth, thereby improving the separation of solids and water from the diluted bitumen. Larger solid particles are removed in primary solid-liquid centrifuges, and secondary solid-liquid-liquid centrifuges remove further solids and water from the diluted bitumen. Solids and water from the centrifuges are pumped as wet tailings to the tailings pond. Product from froth treatment is directed to upgrading as diluted bitumen.


OIL SANDS FEED
HOT WATER
CAUSTIC ADDITION
CONDITIONING DRUM
STEAM
VIBRATING SCREEN
REJECTS
HOT WATER
MIDDLINGS RECYCLE
FROTH
MIDDLINGS
SAND
SEPARATION CELL
FROTH
SETTLED FROTH
FROTH SETTLER
MIDDLINGS
AIR
SCAVENGER CELLS
RECOVERED FROTH
HEATER/ DEAERATOR
STEAM
NAPHTHA DILUENT
PRIMARY CENTRIFUGES
FILTERS
SECONDARY CENTRIFUGES
DILUTED BITUMEN TO UPGRADING
WET TAILINGS TO TAILINGS POND
WET TAILINGS TO TAILINGS POND

SOURCES: ALLEN, A.R. AND E.R. SANDFORD, 1973
AND
ALSANDS PROJECT GROUP, 1978

FIGURE 2-1

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
HOT WATER EXTRACTION AND
FROTH TREATMENT
MONENCO CONSULTANTS LIMITED

N08240 PFD F24

.2 Tailings Filtration

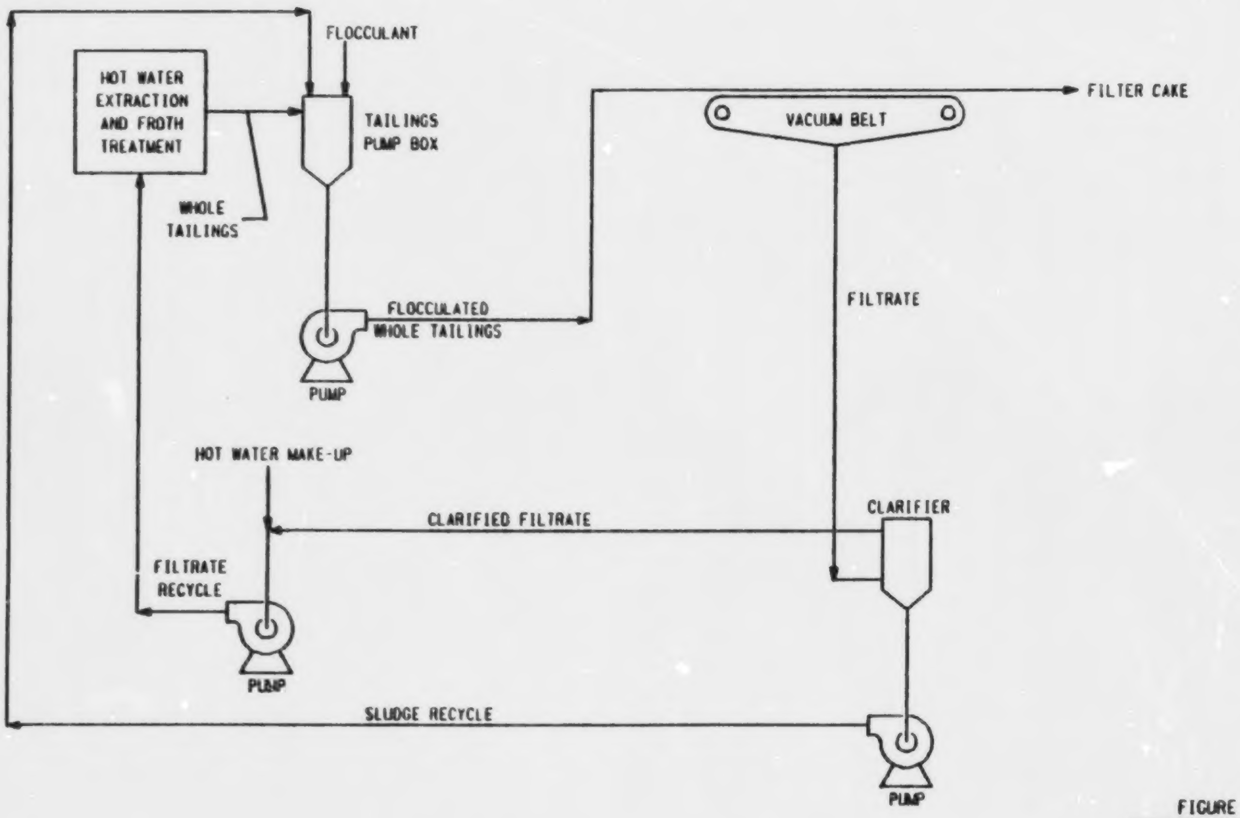
Dewatering of wet tailings from hot water extraction and froth treatment is accomplished by applying the results of a pilot plant vacuum filtration run, as described in United States Patent 4225433, Filtration of Hot Water Extraction Process Whole Tailings, 1980. In this invention, tailings streams from the hot water extraction process are combined as whole tailings. Flocculant (lime) is added to the whole tailings at a rate to provide a flocculant concentration of 300 to 700 mg/L as CaO in the flocculant-whole tailings mixture. The mixture is then subjected to vacuum filtration as shown in Figure 2-2. The flocculant is added to encourage agglomeration of the fine solid particles with coarse solids, thus maximizing solid-liquid separation in vacuum filtration. The filter cake removed from the vacuum filter is dry, containing in the order of 15% water by weight. The filtrate, which may be recycled to hot water extraction, contains 4% total solids by weight and less than 3% fine solids by weight (less than 44 microns).

In the invention (Liu et al 1980), whole tailings are made up of five parts wet tailings from the separation cell (primary tailings) and one part wet tailings from the scavenger cells (secondary tailings). For the purposes of this study, it is assumed that the whole tailings which are subject to vacuum filtration include primary and secondary tailings from hot water extraction (49.5% water, 50.05% solids and 0.55% bitumen on a weight basis) and tailings from froth treatment (77% water, 18.7% solids, 2.5% bitumen and 1.8% naphtha on a weight basis). The tailings stream from froth treatment represents about 5% of the mixture and, although more dilute than the primary and secondary tailings, only reduces the solids content of the mixture by 1.4%. Nevertheless, the fine solids load will be increased and to accommodate this, the quantity of flocculant added is computed at the high end of the range identified in the invention (700 mg/L as CaO in the mixture). Pretreatment prior to mixing or a separate treatment sytem may be required for the tailings stream from froth treatment because of the dilute nature of these tailings and possible naphtha contamination in a combined tailings system. It is assumed that 10% of the bitumen and naphtha in the whole tailings is recovered in the filtrate, with the remainder discharged with the filter cake.

.3 Solvent Extraction

The Dravo Solvent Extraction Process is presently being piloted on oil saturated diatomaceous earth in the United States and has received considerable interest in extracting bitumen from Athabasca oil sands. Process details and waste stream characterization data have been obtained from Dravo Engineers, Inc., Pittsburgh, Pennsylvania (Baczewski pers. comm.).

As shown in the process schematic in Figure 2-3, oil sands are mixed in the feed mixer with a solution of bitumen in solvent (miscella). Bitumen from the oil sands is dissolved in the miscella and is directed with fines to the fines separator. Agglomerated sand - miscella mixture from the feed mixer is forwarded to the percolating bed


FLOCCULANT
HOT WATER EXTRACTION AND FROTH TREATMENT
TAILINGS PUMP BOX
WHOLE TAILINGS
PUMP
FLOCCULATED WHOLE TAILINGS
VACUUM BELT
FILTER CAKE
FILTRATE
HOT WATER MAKE-UP
CLARIFIED FILTRATE
CLARIFIER
FILTRATE RECYCLE
PUMP
SLUDGE RECYCLE
PUMP

SOURCE: LIU, J. K., S. J. LANE AND L. M. CYMBALISTY, U. S. PATENT 4225433, 1980

FIGURE 2-2

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

TAILINGS FILTRATION

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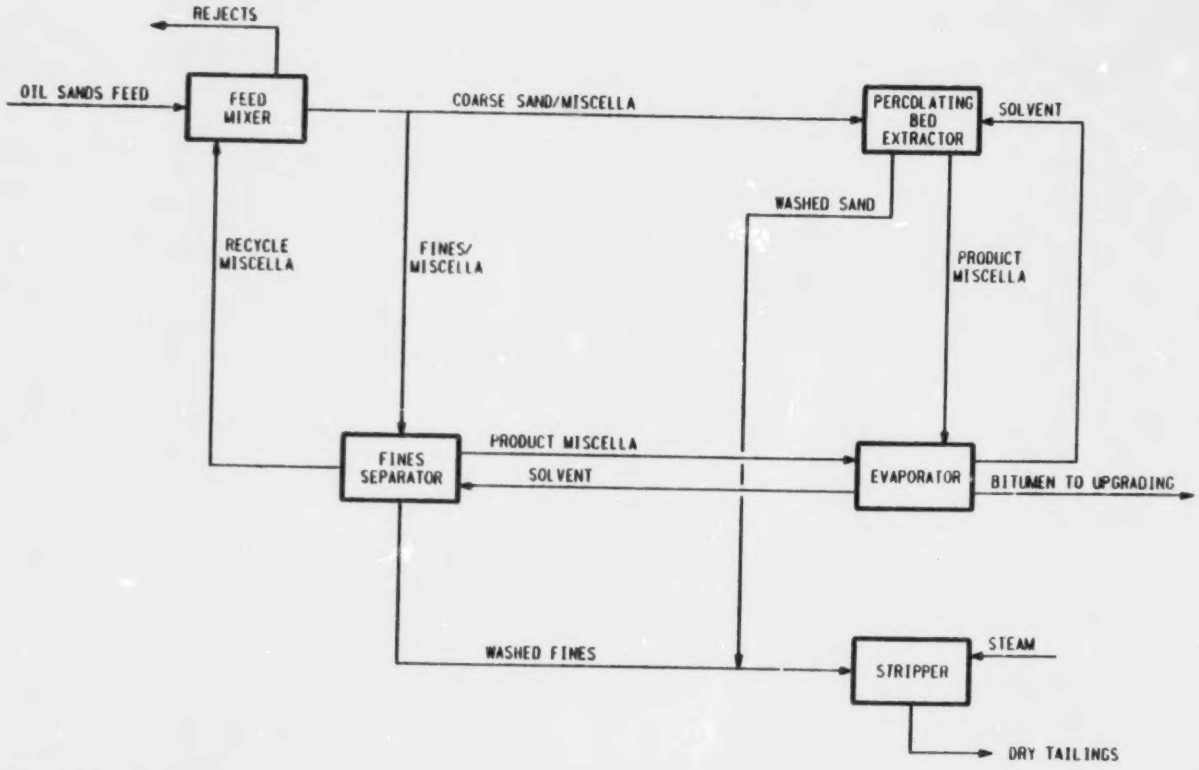

REJECTS
OIL SANDS FEED
FEED MIXER
COARSE SAND/MISCELLA
PERCOLATING BED EXTRACTOR
SOLVENT
WASHED SAND
RECYCLE MISCELLA
FINES/ MISCELLA
PRODUCT MISCELLA
FINES SEPARATOR
PRODUCT MISCELLA
SOLVENT
EVAPORATOR
BITUMEN TO UPGRADING
WASHED FINES
STRIPPER
STEAM
DRY TAILINGS

SOURCE: DRAVO ENGINEERS, INC., 1983

FIGURE 2-3

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

DRAVO SOLVENT EXTRACTION PROCESS

MONENCO CONSULTANTS LIMITED

extractor for separation of the miscella. Clay lumps and rocks (rejects) are removed by screening.

Solvent-washed fines from fines separation and solvent-washed sand from the extractor are drained and contacted with stripping steam in a rotary kiln for solvent removal. Dry tailings from the kiln contain less than 0.1% solvent by weight, as claimed by the process licensers (Baczewski pers. comm.).

Bitumen and solvent are then recovered from the product miscella. The recovered solvent, supplemented with solvent make-up from upgrading, is recycled to the fines separator and extractor.

.4 Direct Coking

The Lurgi Ruhrgas (LR) Direct Coking Process was developed jointly by Lurgi GmbH and Ruhrgas AG. in West Germany. This carbon removal process was originally piloted in the 1950's for the production of gas from coal fines and subsequent combustion of residual hot char for steam generation. The high flexibility of the process has led to commercial scale cracking units which produce olefins from crude oil and pilot scale retorting units for oil sands and heavy oils (Rammler 1982).

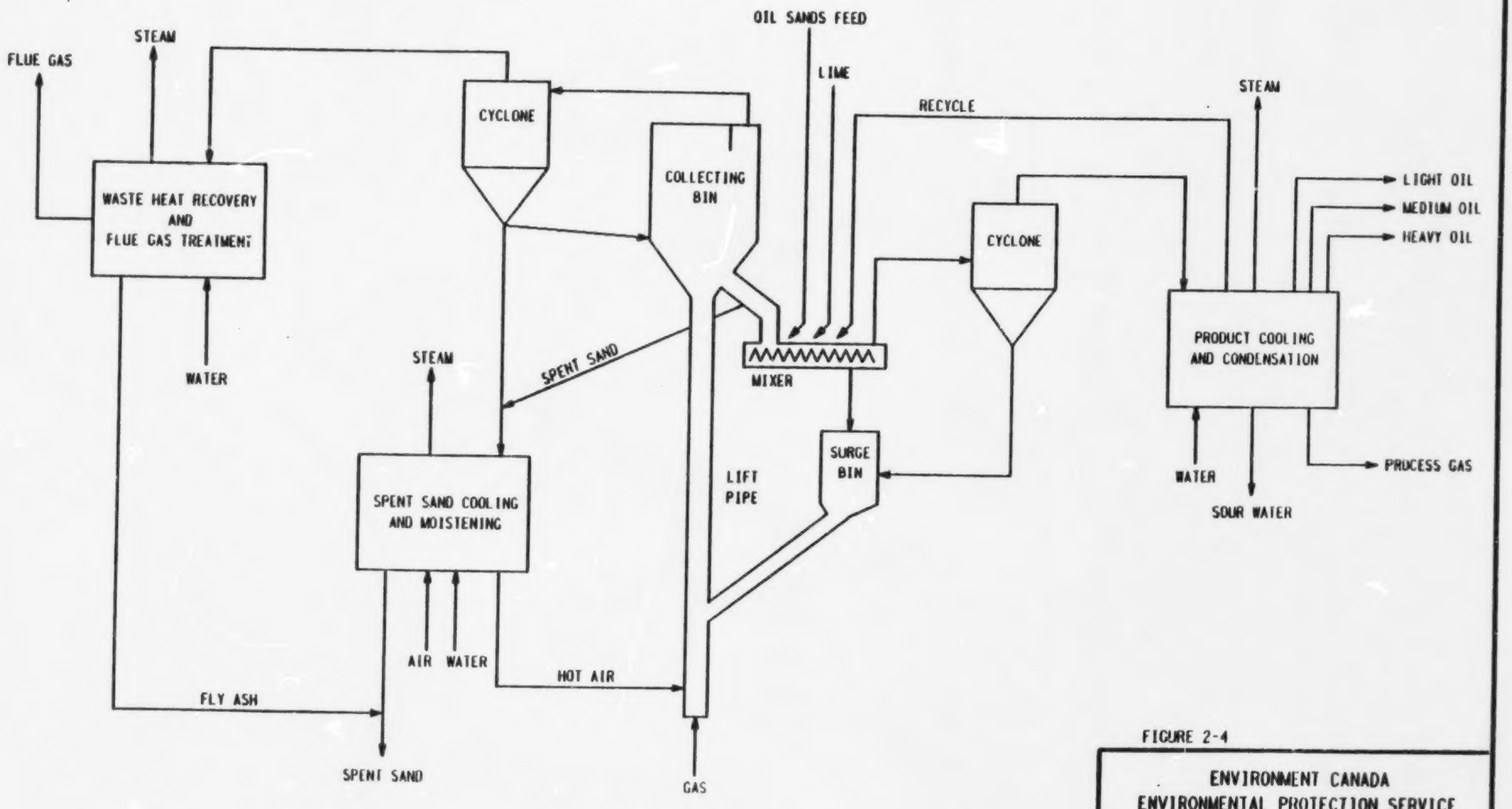
The LR Process for retorting raw oil sands is shown in Figure 2-4. Oil sands are fed to the reactor after screening and are mixed with a hot fine-grained heat carrier. A special double screw mixer quickly and intimately blends the feed with the heat carrier and permits the addition of lime for desulphurization. Spent sand from the reactor is utilized as the heat carrier. Gaseous and vapourous coker products are separated from the heat carrier, fines are removed, and the products are cooled and condensed to three intermediate liquid products.

The fine-grained solids (spent sand) serving as a heat carrier are pneumatically lifted to the collecting bin and at the same time, pyrolysis residues are combusted to meet the heat demand of the system. Flue gases are directed to waste heat recovery (steam production) and flue gas treatment prior to being emitted. Surplus residue is continuously withdrawn, cooled with waste heat recovery, and moistened. Spent sand includes surplus residue from the collecting bin, gypsum and unreacted lime from desulphurization, and fly ash removed from the direct coking flue gas.

273 UPGRADING

.1 Fluid Coking

Fluid coking is a well established process for upgrading heavy hydrocarbon feeds. Two of the largest fluid coking units are in operation at Syncrude. As shown in Figure 2-5, bitumen is injected into a bed of fluid coke in the reactor where it is thermally cracked to produce

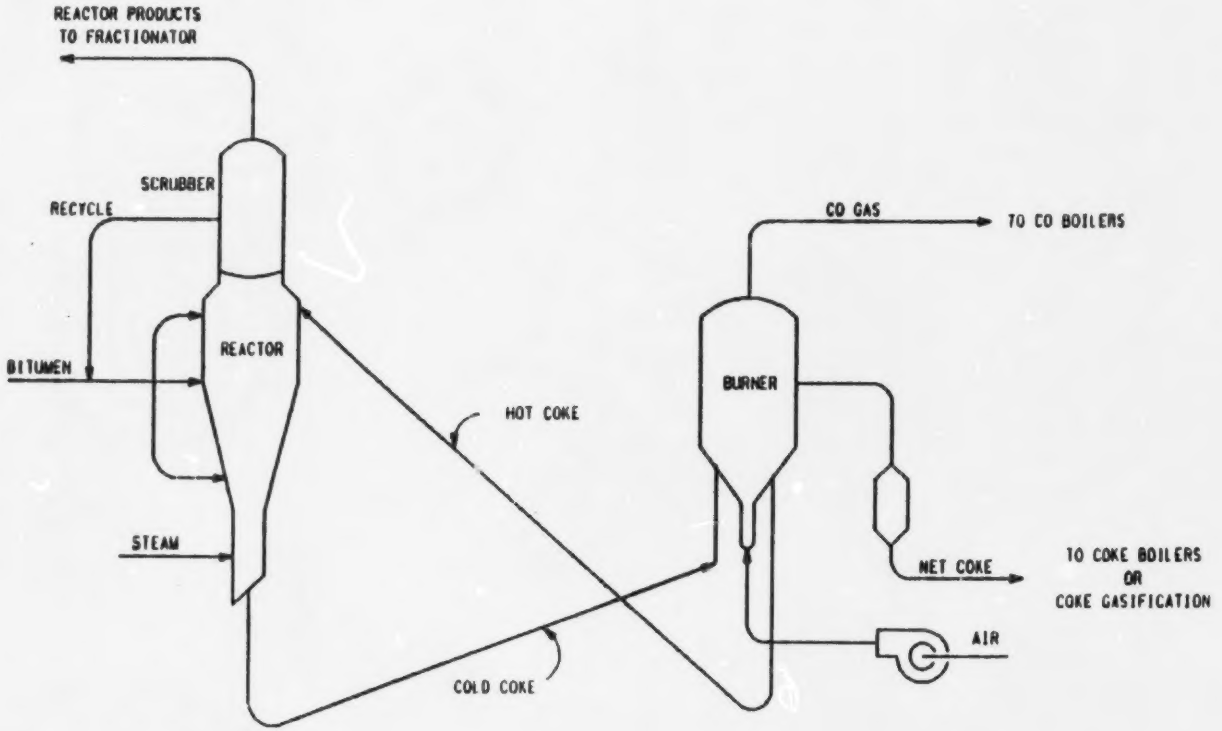

FLUE GAS
STEAM
WASTE HEAT RECOVERY AND FLUE GAS TREATMENT
WATER
CYCLONE
STEAM
SPENT SAND
SPENT SAND COOLING AND MOISTENING
AIR
WATER
FLY ASH
SPENT SAND
HOT AIR
COLLECTING BIN
LIFT PIPE
GAS
OIL SANDS FEED
LIME
RECYCLE
MIXER
SURGE BIN
CYCLONE
STEAM
PRODUCT COOLING AND CONDENSATION
LIGHT OIL
MEDIUM OIL
HEAVY OIL
WATER
SOUR WATER
PROCESS GAS

SOURCE: RAMMLER, R.W., 1982

FIGURE 2-4

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
LURGI RUHRGAS DIRECT
COKING PROCESS
MONENCO CONSULTANTS LIMITED

MONENCO CONSULTANTS LIMITED


REACTOR PRODUCTS
TO FRACTIONATOR
SCRUBBER
RECYCLE
REACTOR
BITUMEN
STEAM
HOT COKE
COLD COKE
BURNER
CO GAS
TO CO BOILERS
NET COKE
TO COKE BOILERS
OR
COKE GASIFICATION
AIR

SOURCE: EGGLESTONE, A.E. and T.H. WISE, 1976

FIGURE 2-5

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

FLUID COKING

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lighter liquids, gas and coke. A portion of the coke produced is burned with air in the burner to generate the heat requirements of the process. Products of the combustion of coke in the burner, known as CO gas, are routed to the CO boilers where they are burned with supplementary fuel to raise steam.

Gases and liquid products from the reactor are scrubbed for solids removal and the heavier fraction (boiling point greater than 525°C) is condensed and recycled to the reactor. The raw distillate products are fractionated into naphtha, and combined light and heavy gas oil streams which are further treated in secondary upgrading.

.2 Flexicoking

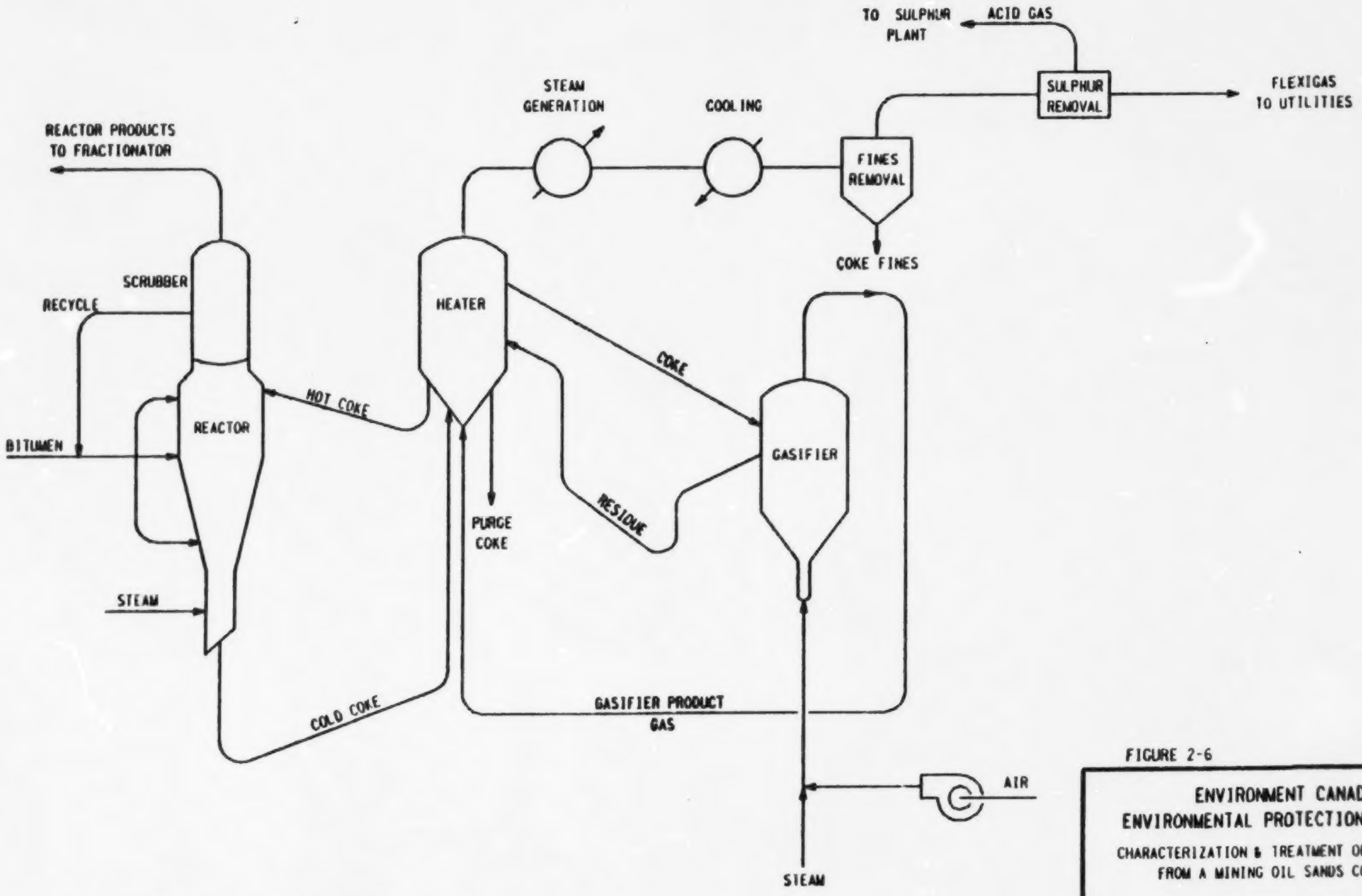
Flexicoking, which is an extension of the fluid coking technology, is a proprietary process of Exxon. The first commerical Flexicoking unit, in operation in Japan, has demonstrated reliable and continuous operation. Two additional Flexicoking units are planned for startup in 1983 and others are at the design stage (Pagel et al 1982). Figure 2-6 illustrates the Flexicoking process.

The primary conversion to liquid products and light ends in the reactor is the same as for fluid coking. The coker burner is replaced with a heater and gasifier. Coke is gasified to a low joule gas in a reducing atmosphere with air. Most of the coke is consumed in the gasification process with only a small coke purge stream (char) removed from the system. The low joule gas, known as flexigas, is scrubbed for the removal of entrained coke fines, is contacted with an amine solution for H_2S removal and is forwarded to utilities as a fuel gas.

.3 H-Oil

The H-Oil hydrocracking process is jointly licenced by Hydrocarbon Research, Inc. and Texaco Development Corporation. This catalytic primary upgrading process is applied in this study to illustrate hydrogen addition technology for upgrading Athabasca bitumen as an alternative to the carbon rejection technologies such as fluid coking and Flexicoking. Major commercial installations utilizing the hydrogen addition technology are in operation in refineries in Kuwait and Mexico, and two facilities in the United States are at advanced stages of development (Rubero and Balakrishnan 1982). The H-Oil process has been tested successfully in laboratory and pilot plant facilities on Athabasca bitumen (Johnson et al 1977).

Within the H-Oil process, bitumen and hydrogen make-up are introduced to the ebullating-bed reactor under the feed distributor located at the bottom of the reactor, as shown in Figure 2-7. Liquid hydrocarbons are recycled from the reactor and are mixed with the feed via the ebullating pump. The mixture is introduced uniformly to the ebullating bed by the distributor plate.


TO SULPHUR PLANT
ACID GAS
SULPHUR REMOVAL
FLEXIGAS TO UTILITIES
STEAM GENERATION
COOLING
REACTOR PRODUCTS TO FRACTIONATOR
FINES REMOVAL
COKE FINES
SCRUBBER
RECYCLE
HEATER
COKE
HOT COKE
BITUMEN
REACTOR
GASIFIER
PURGE COKE
RESIDUE
STEAM
COLD COKE
GASIFIER PRODUCT GAS
AIR
STEAM

SOURCE: EGGLESTONE, A.E. AND T.H.WISE, 1976

FIGURE 2-6

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

FLEXICOKING

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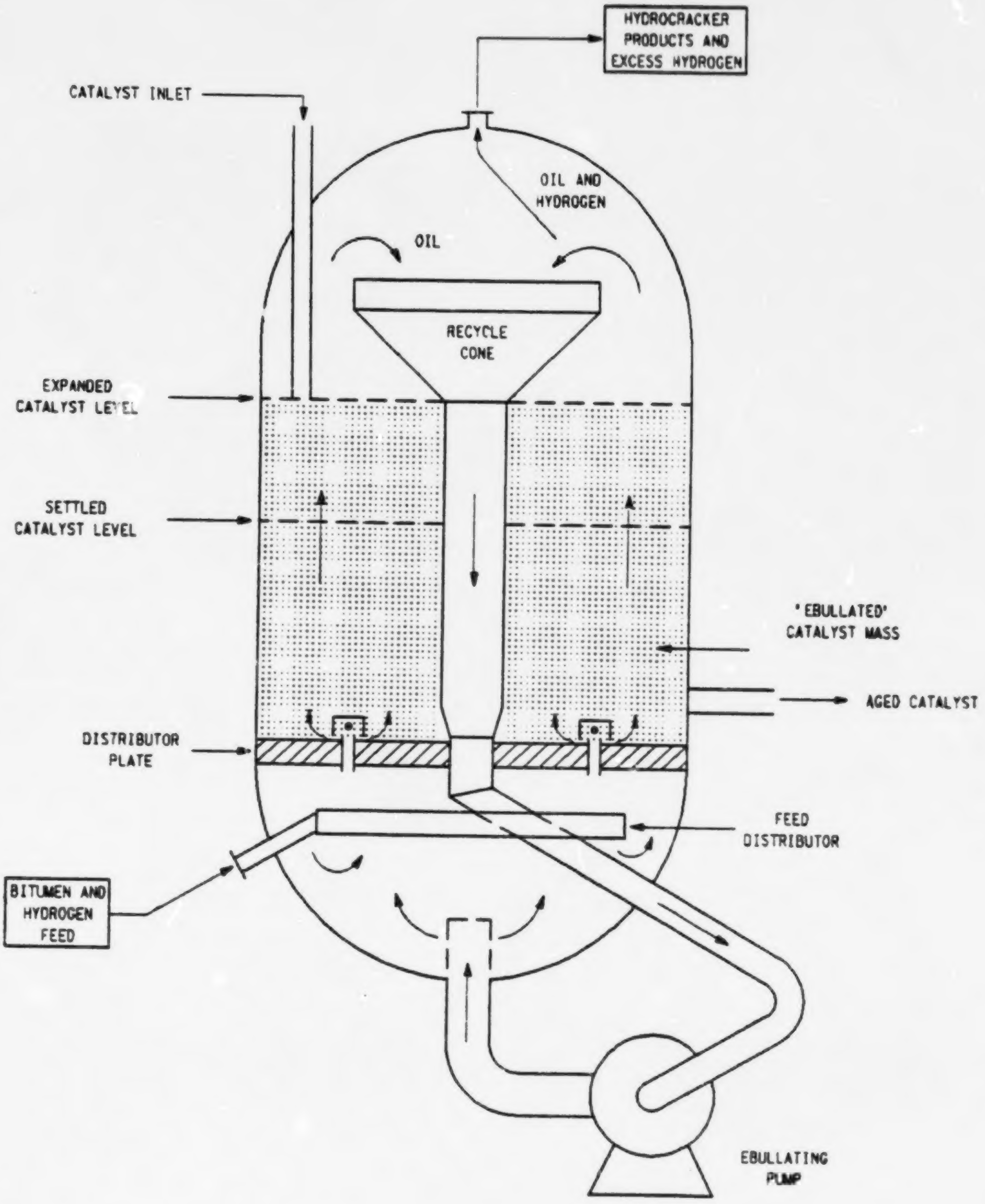
HYDROCRACKER PRODUCTS AND EXCESS HYDROGEN
CATALYST INLET
OIL AND HYDROGEN
OIL
RECYCLE CONE
EXPANDED CATALYST LEVEL
SETTLED CATALYST LEVEL
'EBULLATED' CATALYST MASS
AGED CATALYST
DISTRIBUTOR PLATE
FEED DISTRIBUTOR
BITUMEN AND HYDROGEN FEED
EBULLATING PUMP

FIGURE 2-7

SOURCES: RUBERO, P.A. AND S. BALAKRISHAN, 1982
AND
JOHNSON, C.A. et al, 1977

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

H-OIL EBULLATING BED REACTOR

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The ebullating bed of catalyst is expanded and is in a state of motion induced by the inflow of the vapour and liquid feed. This permits intimate contact between the oil, hydrogen, and catalyst within the bed where hydrocracking, desulphurization, denitrification, demetallization and saturation take place. Aged catalyst may be removed from the reactor continuously or periodically, with fresh catalyst added to the bed to maintain the required level of catalyst activity.

Products from the system include light ends which may be utilized as plant process gas after sulphur removal, naphtha and light and heavy gas oil which are further treated in secondary upgrading, and a pitch residuum (boiling point greater than 524°C) which is utilized in pitch boilers or in the hydrogen plant.

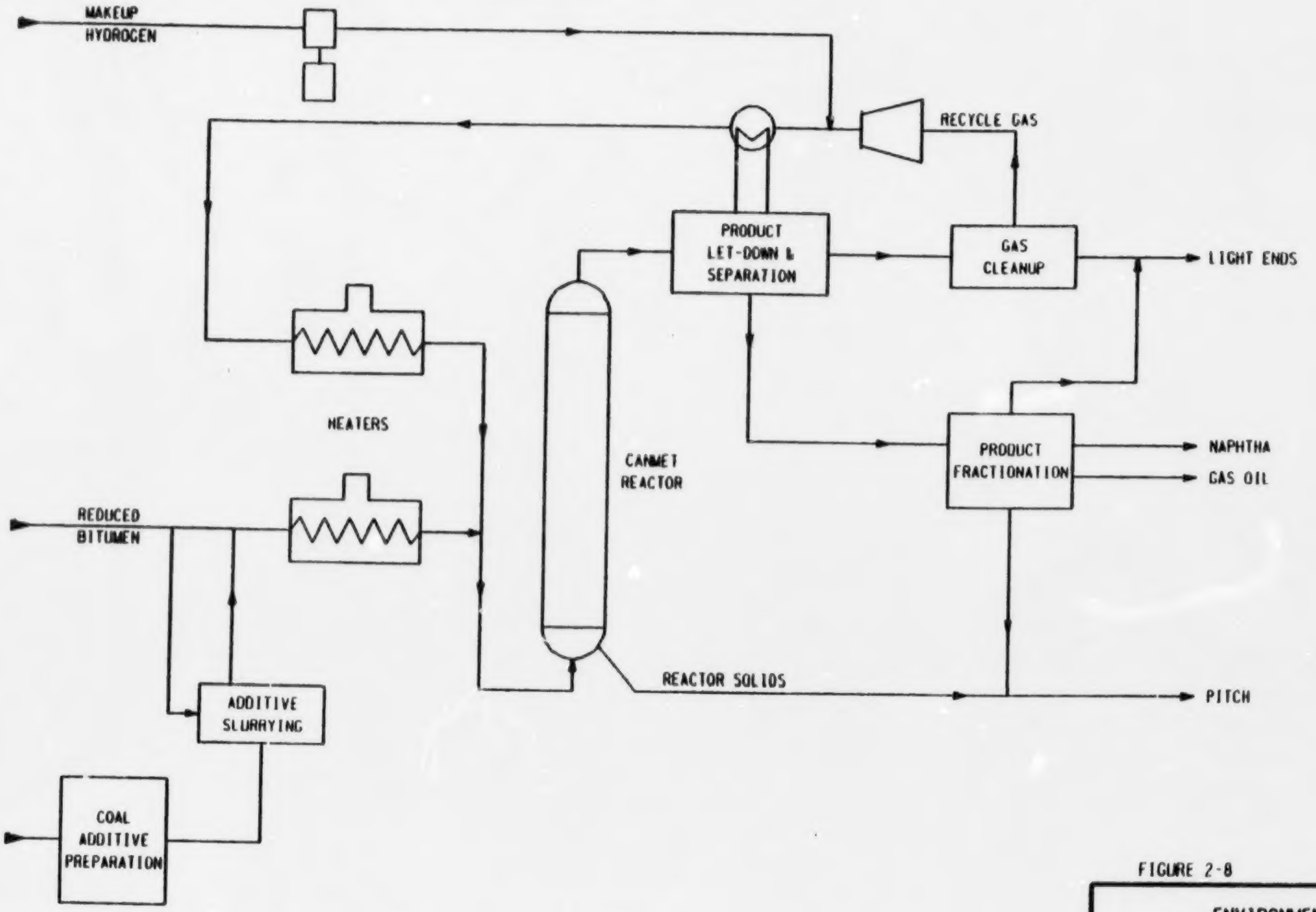
.4 CANMET

The CANMET hydrocracking process has been developed by the Federal Department of Energy, Mines, and Resources. Partec Lavalin Inc. and Petro-Canada, licensors of the process, are undertaking a commercialization program which includes the installation of a CANMET commerical demonstration unit at Petro-Canada's refinery near Montreal (Chambers et al 1982). Pilot plant units have successfully upgraded a variety of heavy fieldstocks, including Athabasca bitumen.

The CANMET hydrocracking process is a non-catalytic hydrogen addition process that operates at a lower pressure than other hydrocracking processes. The process uses an additive of pulverized coal impregnated with a metallic salt, such as iron sulphate (Menzies et al 1981). As shown in Figure 2-8, reduced bitumen (the heavy ends from atmospheric and vacuum distillation units) are mixed with the slurried coal additive, heated and fed to the CANMET reactor with hydrogen. The additive prevents the deposition of coke within the reactor and attracts metals such as nickel and vanadium from the feed bitumen, removing them from the liquid products. Oil and hydrogen rise through a bed of particles composed of additive residues and deposited feed metals. Solids are continuously removed from the reactor. The gaseous and liquid products of hydrocracking are removed overhead and are separated and fractionated prior to secondary upgrading. The pitch residue, which includes solids from the reactor and heavy ends from fractionation, is routed to utilities.

.5 Eureka

The Eureka thermal cracking process was developed by Kureha Chemical Industry Co., Ltd., and Chiyoda Chemical Engineering and Construction Co., Ltd. for upgrading refinery vacuum residue oil. The process was commercialized in Japan in 1976. Recently, pilot scale tests on whole and reduced Athabasca bitumen have demonstrated the applicability of the upgrading process to Athabasca bitumen (Aiba et al 1982).


MAKEUP HYDROGEN
RECYCLE GAS
PRODUCT LET-DOWN & SEPARATION
GAS CLEANUP
LIGHT ENDS
HEATERS
CANMET REACTOR
PRODUCT FRACTIONATION
NAPHTHA
GAS OIL
REDUCED BITUMEN
ADDITIVE SLURRYING
REACTOR SOLIDS
PITCH
COAL ADDITIVE PREPARATION

SOURCE: MENZIES, M.A. et al, 1981

FIGURE 2-8

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

CANMET HYDROCRACKING

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N00253..PFD F24

The Eureka process is a carbon rejection process similar to delayed coking, but differs from the conventional coking process by preventing the formation of coke in the reactor. Superheated steam is injected to strip the cracked products out of the reactor and provide a portion of the reactor heat requirements.

As shown in Figure 2-9, the bitumen feed is preheated and introduced to the bottom of the fractionator where it is mixed with a recycle oil from the fractionator. The mixture is pumped to the charge heater and introduced to the batch-operated reactors. The bitumen is cracked to lighter gaseous and liquid products and a viscous pitch bottom material is steam stripped from the reactor. Products from the reactors are removed overhead and fractionated to intermediate product streams. The pitch is pumped to the flaker where it is solidified and flaked.

.6 Secondary Upgrading

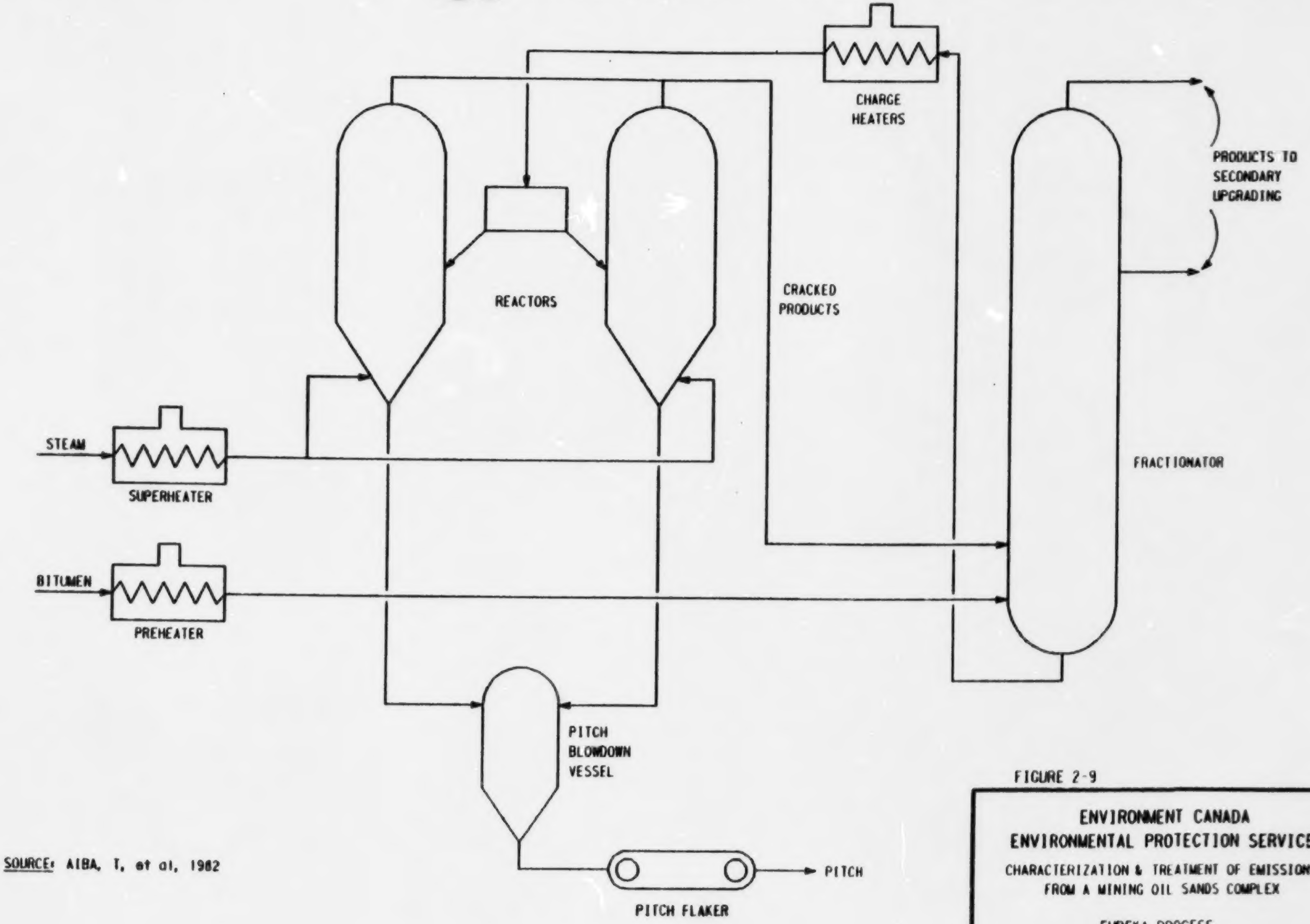
Intermediate products from primary upgrading and products of direct coking (Options 10 and 15) require further sulphur removal and treatment before they are blended as synthetic crude. Secondary upgrading is accomplished in naphtha, distillate and gas oil hydrotreaters. These are conventional processes with proven commercial experience.

Other process units within upgrading which are common to all options include the gas recovery unit, amine plant, sulphur plant, hydrogen plant and sour water stripper. In all options except Options 10 and 15, diluent or solvent recovery and preparation units are required. Figure 2-10 shows a generalized concept of the process units within upgrading.

Product gases and vapours from primary upgrading and light ends from the hydrotreaters are separated by distillation in the gas recovery unit. Sour process gases from the gas recovery unit are stripped of sulphur-containing compounds by contact with amine solution in the amine plant. The sweetened process gas is utilized as a fuel in upgrading and utilities. The amine solution is regenerated and the acid gases are forwarded to the sulphur plant.

Multi-train Claus sulphur recovery units followed by Shell Claus Off-Gas Treating (SCOT) units recover 99.9% of the sulphur feed to the sulphur plant. Within the Claus units, elemental sulphur is formed thermally and catalytically. Tail gases from the Claus units are cleaned up in the SCOT units by reduction and amine absorption. The treated gases, which contain only traces of H_2S, are incinerated before venting to the atmosphere.

Wastewater from various unit processes, including the amine plant, SCOT units and the hydrotreaters, is stripped of H_2S and NH_3 in the two stage sour water stripper. Stripped water which is not used for make-up is discharged from upgrading.


CHARGE HEATERS
PRODUCTS TO SECONDARY UPGRADING
REACTORS
CRACKED PRODUCTS
FRACTIONATOR
STEAM
SUPERHEATER
BITUMEN
PREHEATER
PITCH BLOWDOWN VESSEL
PITCH
PITCH FLAKER

SOURCE: AIBA, T, et al, 1982

FIGURE 2-9

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

EUREKA PROCESS

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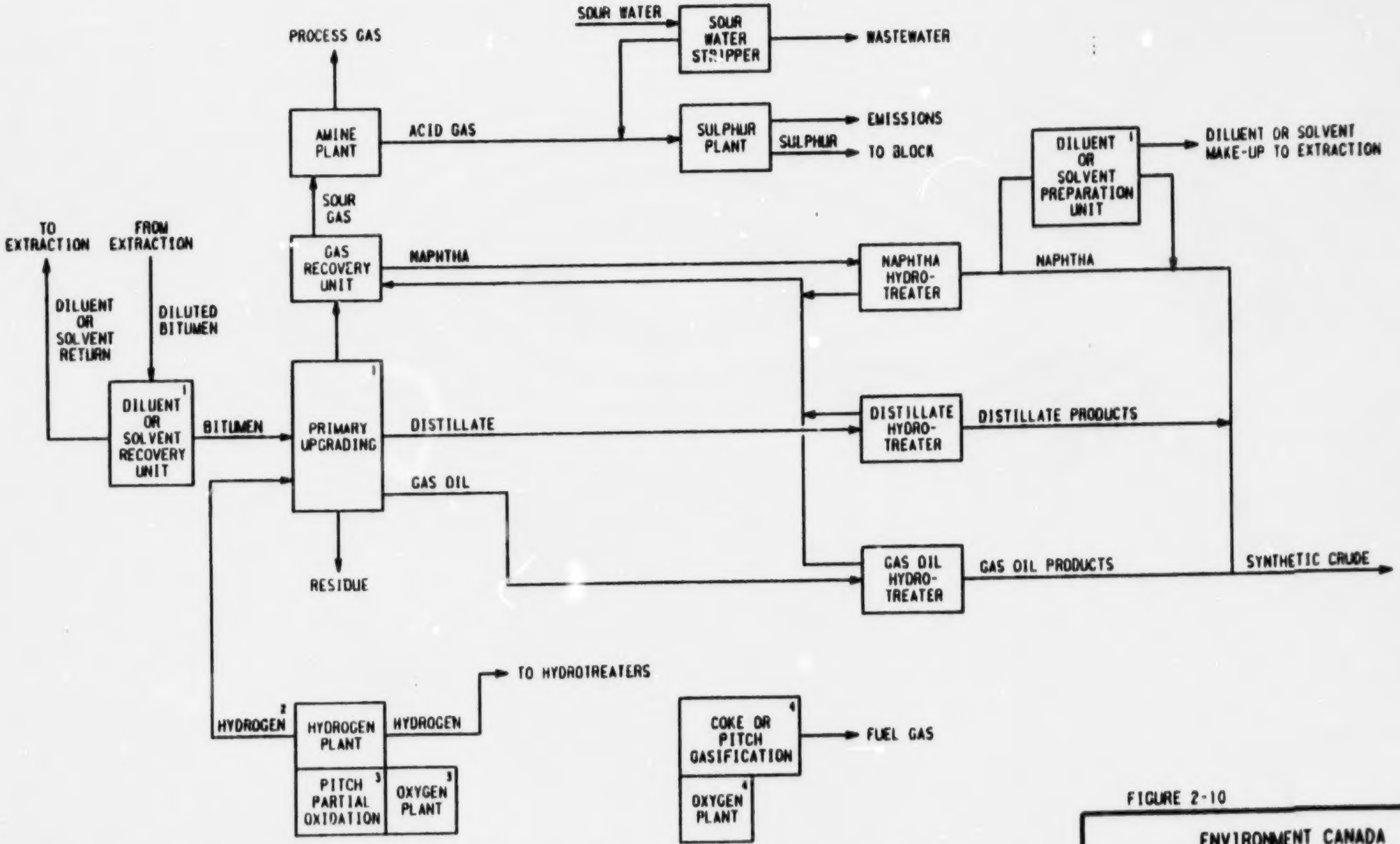
PROCESS GAS
SOUR WATER
SOUR WATER STRIPPER
WASTEWATER
AMINE PLANT
ACID GAS
SULPHUR PLANT
EMISSIONS
SULPHUR
TO BLOCK
DILUENT OR SOLVENT PREPARATION UNIT 1
DILUENT OR SOLVENT MAKE-UP TO EXTRACTION
SOUR GAS
TO EXTRACTION
FROM EXTRACTION
GAS RECOVERY UNIT
NAPHTHA
NAPHTHA HYDRO-TREATER
NAPHTHA
DILUENT OR SOLVENT RETURN
DILUTED BITUMEN
DILUENT OR SOLVENT RECOVERY UNIT 1
BITUMEN
PRIMARY UPGRADING 1
DISTILLATE
DISTILLATE HYDRO-TREATER
DISTILLATE PRODUCTS
GAS OIL
RESIDUE
GAS OIL HYDRO-TREATER
GAS OIL PRODUCTS
SYNTHETIC CRUDE
TO HYDROTREATERS
HYDROGEN 2
HYDROGEN PLANT
HYDROGEN
PITCH PARTIAL OXIDATION 3
OXYGEN PLANT 3
COKE OR PITCH GASIFICATION 4
FUEL GAS
OXYGEN PLANT 4

NOTES: 1. ALL OPTIONS EXCEPT 10 & 15
2. OPTIONS 4, 5, 6, 12 & 13
3. OPTIONS 5 & 12
4. OPTIONS 2 & 7

FIGURE 2-10

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

UPGRADING

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[illegible]

Hydrogen, which is required in secondary upgrading and in the hydrogen addition primary upgrading processes, is generated by steam reformation of natural gas and process gas. In Options 5 and 12, hydrogen is also produced from the synthesis gas generated from the partial oxidation of pitch.

In Options 2 and 7, a medium joule fuel gas is produced by the gasification of coke and pitch. For the purposes of identifying waste streams, the Texaco partial oxidation process is applied to the gasification of coke or pitch to produce fuel gas or hydrogen. Oxygen, required in the gasification of coke or pitch, is generated by compression of air and subsequent distillation of oxygen from the nitrogen.

274 OPTION DESCRIPTIONS

In this section, the major unit processes within mining, extraction, upgrading and utilities are identified and significant raw materials and products are quantified. Option descriptions are provided in Tables 2-2 to 2-16. Figures 2-11 to 2-25 are block flow diagrams of each option which identify the major components of the oil sands processing facilities. Gaseous, liquid and solid wastes which are generated in all process areas are not identified on the block flow diagrams. This waste management information is presented in Part 3.

Stream day (sd) raw material and product flows are used to identify process capabilities and production rates and are representative of average day operational rates.

TABLE 2-2

Option Description - Option 1

HOT WATER EXTRACTION/FLUID COKING/CO AND COKE BOILERS

MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers	
	Oil Sands Mined	431635 t/sd
EXTRACTION	Hot Water Extraction	
	Oil Sands Feed to Extraction	257210 t/sd
	Bitumen Feed to Extraction	28510 m^3/sd
UPGRADING	Fluid Coking	
	Bitumen Feed to Upgrading	23500 m^3/sd
	Synthetic Crude Production	20000 m^3/sd
	Process Gas Production	101950 m^3/hr
	Coke Production	2868 t/sd
	Sulphur Production	837.5 t/sd
UTILITIES		
	Steam: CO Boilers + FGD	608000 m^3/hr CO + 8000 m^3/hr PG
	Coke Boilers + FGD	112000 kg/hr Coke + 90000 m^3/hr PG
	Superheaters	7700 m^3/hr NG + 2200 m^3/hr PG
	Power: Back Pressure and Steam Turbines	

CO Coke Gas from Fluid Coking
PG Process Gas
NG Natural Gas

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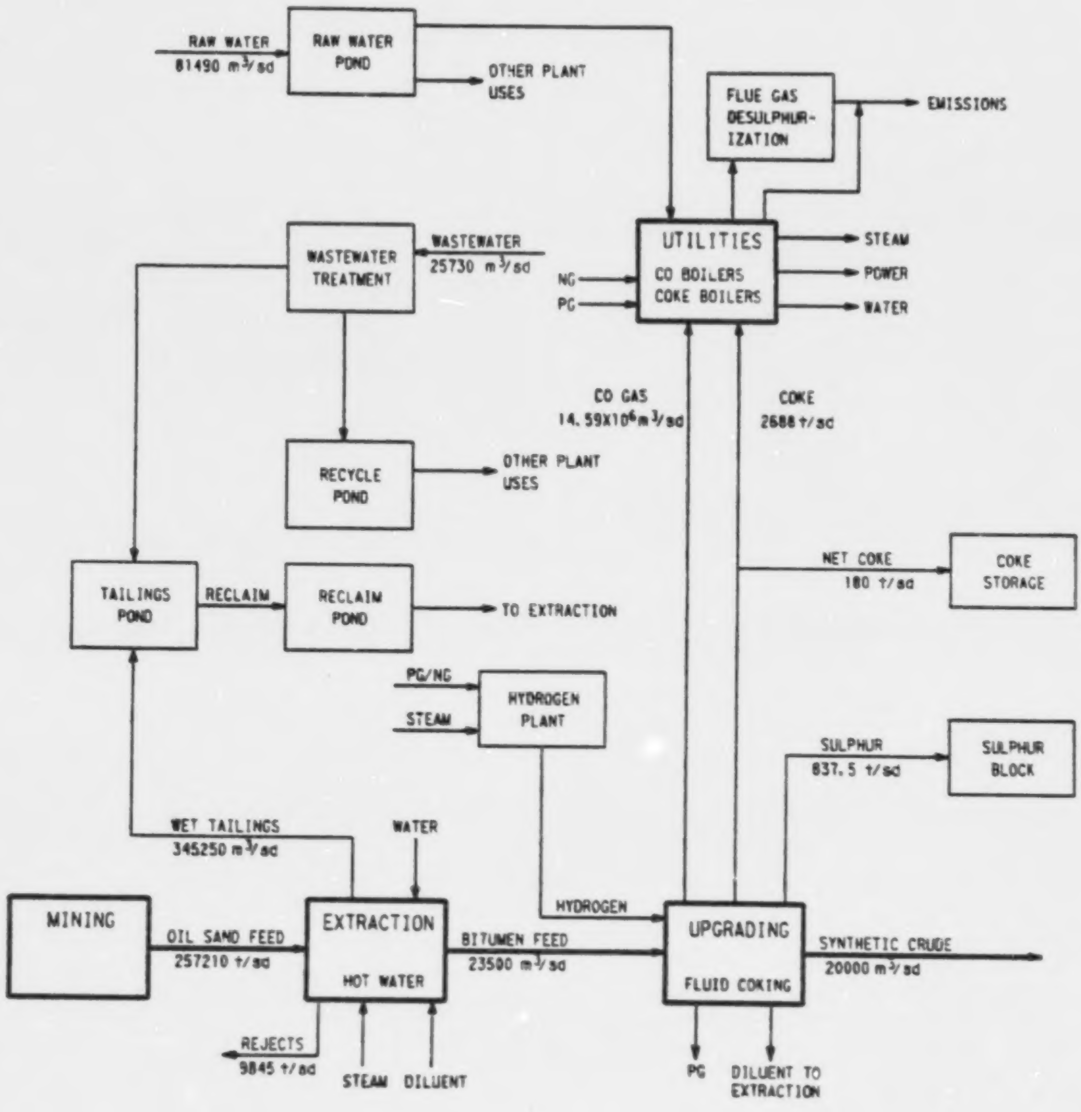
BLOCK FLOW DIAGRAM


RAW WATER
81490 m³/sd
RAW WATER POND
OTHER PLANT USES
FLUE GAS DESULPHUR-IZATION
EMISSIONS
WASTEWATER TREATMENT
WASTEWATER
25730 m³/sd
UTILITIES
CO BOILERS
COKE BOILERS
NG
PG
STEAM
POWER
WATER
CO GAS
14.59X10⁶ m³/sd
COKE
2688 t/sd
RECYCLE POND
OTHER PLANT USES
NET COKE
180 t/sd
COKE STORAGE
TAILINGS POND
RECLAIM
RECLAIM POND
TO EXTRACTION
PG/NG
STEAM
HYDROGEN PLANT
SULPHUR
837.5 t/sd
SULPHUR BLOCK
WET TAILINGS
345250 m³/sd
WATER
HYDROGEN
MINING
OIL SAND FEED
257210 t/sd
EXTRACTION
HOT WATER
BITUMEN FEED
23500 m³/sd
UPGRADING
FLUID COKING
SYNTHETIC CRUDE
20000 m³/sd
REJECTS
9845 t/sd
STEAM
DILUENT
PG
DILUENT TO EXTRACTION

PG - PROCESS GAS

NG - NATURAL GAS

FIGURE 2-11

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 1 HOT WATER EXTRACTION/FLUID COKING/
CO & COKE BOILERS

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TABLE 2-3

Option Description - Option 2

	HOT WATER EXTRACTION/TAILINGS FILTRATION/FLUID COKING/ GASIFICATION OF COKE	
MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers	
	Oil Sands Mined	431635 t/sd
EXTRACTION	Hot Water Extraction with Tailings Filtration	
	Oil Sands Feed to Extraction	257210 t/sd
	Bitumen Feed to Extraction	28510 m^3/sd
UPGRADING	Fluid Coking	
	Bitumen Feed to Upgrading	23500 m^3/sd
	Synthetic Crude Production	20000 m^3/sd
	Process Gas Production	101950 m^3/hr
	Medium Joule Fuel Gas Production	168500 m^3/hr
	Sulphur Production	1071 t/sd
UTILITIES		
	Steam: CO Boilers + FGD	608000 m^3/hr CO + 8000 m^3/hr PG
	FG Boilers	168500 m^3/hr FG + 2900 m^3/hr NG
	WH Boilers	387000 m^3/hr WH + 5000 m^3/hr NG
	NG Superheaters	15300 m^3/hr NG
	PG Superheaters	2100 m^3/hr PG
	Power: Gas, Back Pressure and Steam Turbines	

CO Coke Gas from Fluid Coking
PG Process Gas
FG Medium Joule Fuel Gas from Coke Gasification
WH Waste Heat from Gas Turbines

BLOCK FLOW DIAGRAM

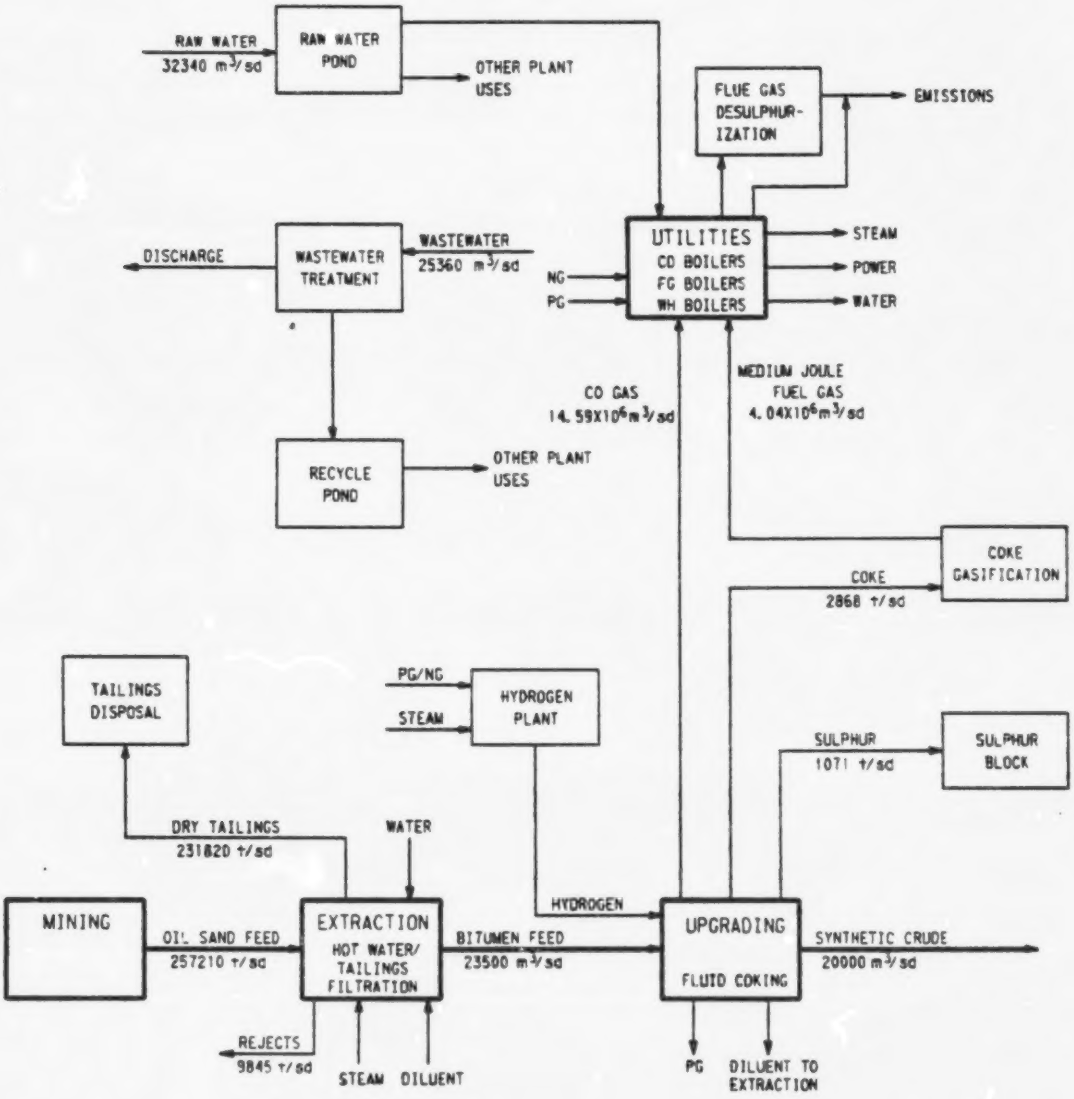
RAW WATER
32340 m³/sd
RAW WATER POND
OTHER PLANT USES
FLUE GAS DESULPHURIZATION
EMISSIONS
UTILITIES
CO BOILERS
FG BOILERS
WH BOILERS
NG
PG
STEAM
POWER
WATER
DISCHARGE
WASTEWATER TREATMENT
WASTEWATER
25360 m³/sd
CO GAS
14.59X10⁶m³/sd
MEDIUM JOULE FUEL GAS
4.04X10⁶m³/sd
RECYCLE POND
OTHER PLANT USES
COKE GASIFICATION
COKE
2868 t/sd
TAILINGS DISPOSAL
PG/NG
STEAM
HYDROGEN PLANT
SULPHUR
1071 t/sd
SULPHUR BLOCK
DRY TAILINGS
231820 t/sd
WATER
HYDROGEN
MINING
OIL SAND FEED
257210 t/sd
EXTRACTION
HOT WATER/ TAILINGS FILTRATION
BITUMEN FEED
23500 m³/sd
UPGRADING
FLUID COKING
SYNTHETIC CRUDE
20000 m³/sd
REJECTS
9845 t/sd
STEAM
DILUENT
PG
DILUENT TO EXTRACTION

FIGURE 2-12

PG - PROCESS GAS
NG - NATURAL GAS
FG - MEDIUM JOULE FUEL GAS
WH - WASTE HEAT

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION 2 HOT WATER EXTRACTION/TAILINGS FILTRATION/FLUID COKING/ GASIFICATION OF COKE

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TABLE 2-4

Option Description - Option 3

HOT WATER EXTRACTION/FLEXICOKING/FLEXIGAS BOILERS

MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers	
	Oil Sands Mined	431635 t/sd
EXTRACTION	Hot Water Extraction	
	Oil Sands Feed to Extraction	257210 t/sd
	Bitumen Feed to Extraction	28510 m^3/sd
UPGRADING	Flexicoking	
	Bitumen Feed to Upgrading	23500 m^3/sd
	Synthetic Crude Production	20000 m^3/sd
	Process Gas Production	101950 m^3/hr
	Flexigas Production	859000 m^3/hr
	Sulphur Production	1113 t/sd
UTILITIES	Steam: Flexigas Boilers	859000 m^3/hr Flexigas + 45000 m^3/hr NG
	NG Superheater	15000 m^3/hr NG
	Power: Back Pressure and Steam Turbines	

Flexigas Low Joule Fuel Gas from Flexicoking Gasifier
NG Natural Gas

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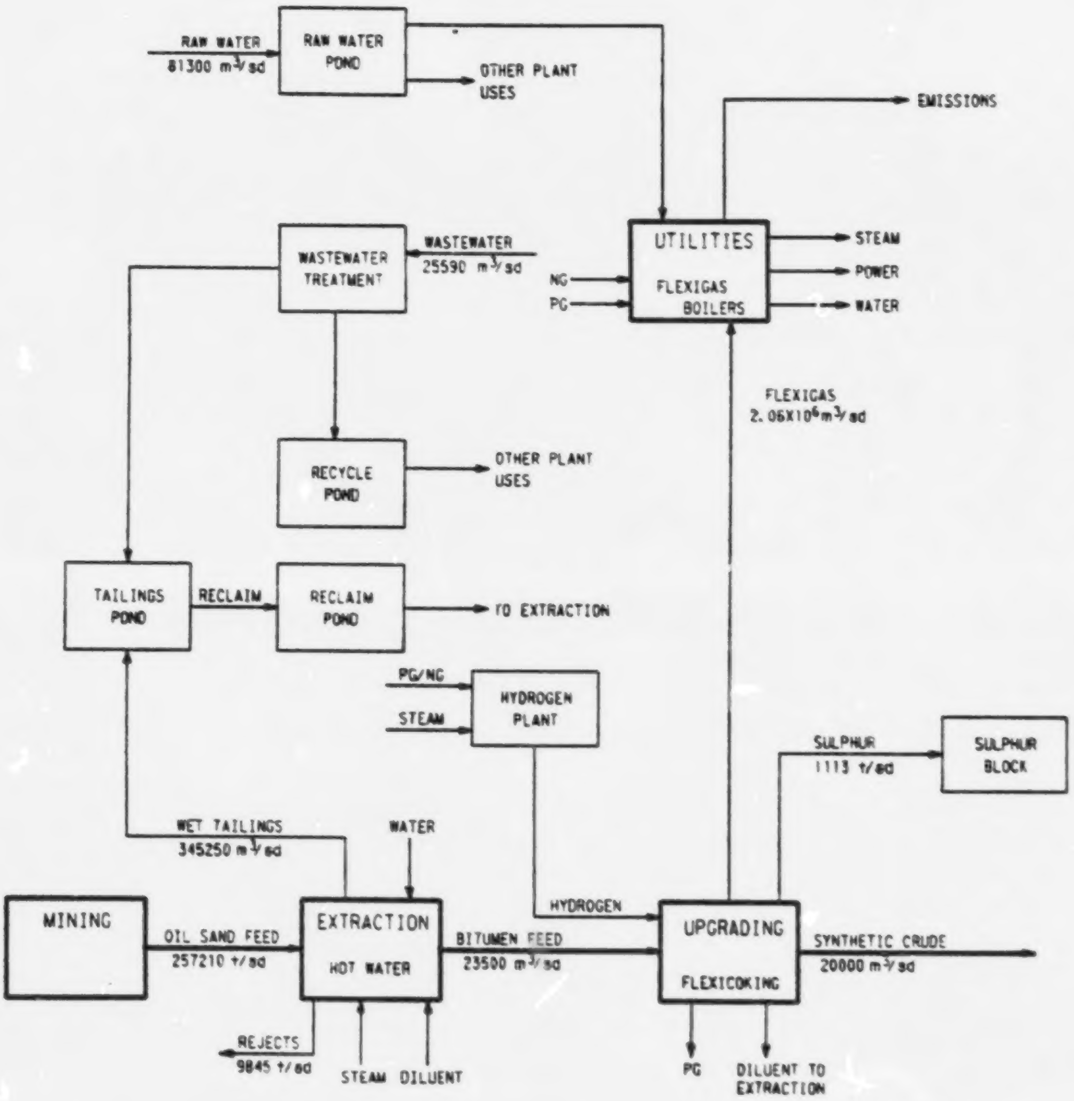
BLOCK FLOW DIAGRAM


RAW WATER
81300 m³/sd
RAW WATER POND
OTHER PLANT USES
EMISSIONS
WASTEWATER TREATMENT
WASTEWATER
25590 m³/sd
NG
PG
UTILITIES
FLEXIGAS BOILERS
STEAM
POWER
WATER
FLEXIGAS
2.06X10⁶m³/sd
RECYCLE POND
OTHER PLANT USES
TAILINGS POND
RECLAIM
RECLAIM POND
TO EXTRACTION
PG/NG
STEAM
HYDROGEN PLANT
SULPHUR
1113 t/sd
SULPHUR BLOCK
WET TAILINGS
345250 m³/sd
WATER
HYDROGEN
MINING
OIL SAND FEED
257210 t/sd
EXTRACTION
HOT WATER
BITUMEN FEED
23500 m³/sd
UPGRADING
FLEXICOKING
SYNTHETIC CRUDE
20000 m³/sd
REJECTS
9845 t/sd
STEAM
DILUENT
PG
DILUENT TO EXTRACTION

PG - PROCESS GAS
NG - NATURAL GAS

FIGURE 2-13

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS FROM A MINING OIL SANDS COMPLEX

OPTION 3 HOT WATER EXTRACTION/FLEXICOKING/ FLEXIGAS BOILERS

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TABLE 2-5

Option Description - Option 4

HOT WATER EXTRACTION/H-OIL/PITCH BOILERS		
MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers	
	Oil Sands Mined	365145 t/sd
EXTRACTION	Hot Water Extraction	
	Oil Sands Feed to Extraction	217590 t/sd
	Bitumen Feed to Extraction	24215 m^3/sd
UPGRADING	H-Oil	
	Bitumen Feed to Upgrading	19880 m^3/sd
	Synthetic Crude Production	20000 m^3/sd
	Process Gas Production	73800 m^3/hr
	Pitch Production	1406 t/sd
	Sulphur Production	926 t/sd
UTILITIES	Steam: Pitch Boilers + FGD	58200 kg/hr Pitch + 40000 m^3/hr NG
	WH Boilers	311000 m^3/hr WH + 2300 m^3/hr NG
	Superheaters	6900 m^3/hr NG
	Power: Gas, Back Pressure and Steam Turbines	

WH Waste Heat from Gas Turbines
NG Natural Gas

BLOCK FLOW DIAGRAM

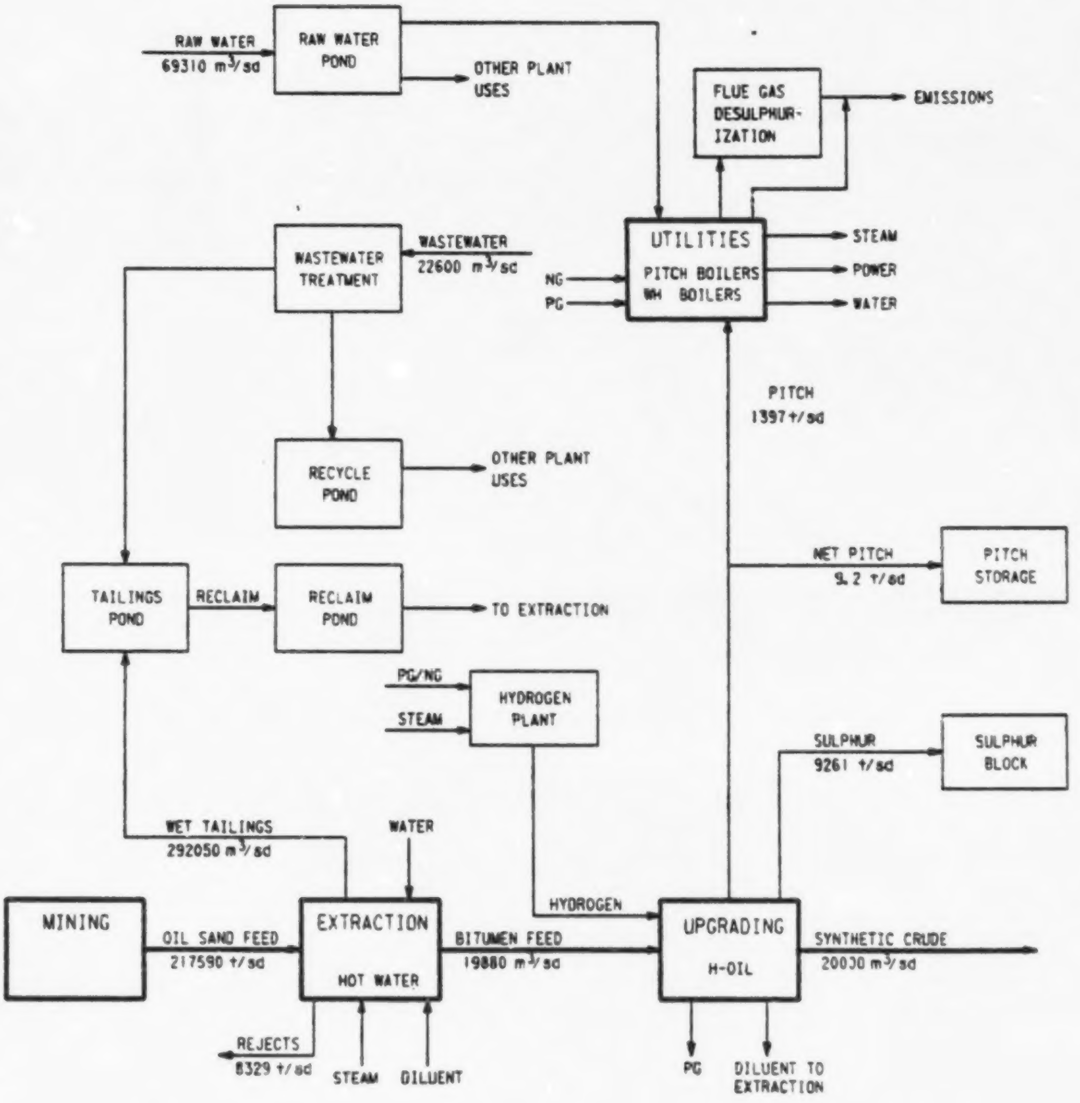

RAW WATER
69310 m³/sd
RAW WATER POND
OTHER PLANT USES
FLUE GAS DESULPHURIZATION
EMISSIONS
WASTEWATER TREATMENT
WASTEWATER
22600 m³/sd
UTILITIES
PITCH BOILERS
WH BOILERS
NG
PG
STEAM
POWER
WATER
PITCH
1397 t/sd
RECYCLE POND
OTHER PLANT USES
NET PITCH
9.2 t/sd
PITCH STORAGE
TAILINGS POND
RECLAIM
RECLAIM POND
TO EXTRACTION
PG/NG
STEAM
HYDROGEN PLANT
SULPHUR
9261 t/sd
SULPHUR BLOCK
WET TAILINGS
292050 m³/sd
WATER
HYDROGEN
MINING
OIL SAND FEED
217590 t/sd
EXTRACTION
HOT WATER
BITUMEN FEED
19880 m³/sd
UPGRADING
H-OIL
SYNTHETIC CRUDE
20030 m³/sd
REJECTS
8329 t/sd
STEAM
DILUENT
PG
DILUENT TO EXTRACTION

FIGURE 2-14

PG - PROCESS GAS
NG - NATURAL GAS
WH - WASTE HEAT

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 4 HOT WATER EXTRACTION/
H-OIL/ PITCH BOILERS

MONENCO CONSULTANTS LIMITED

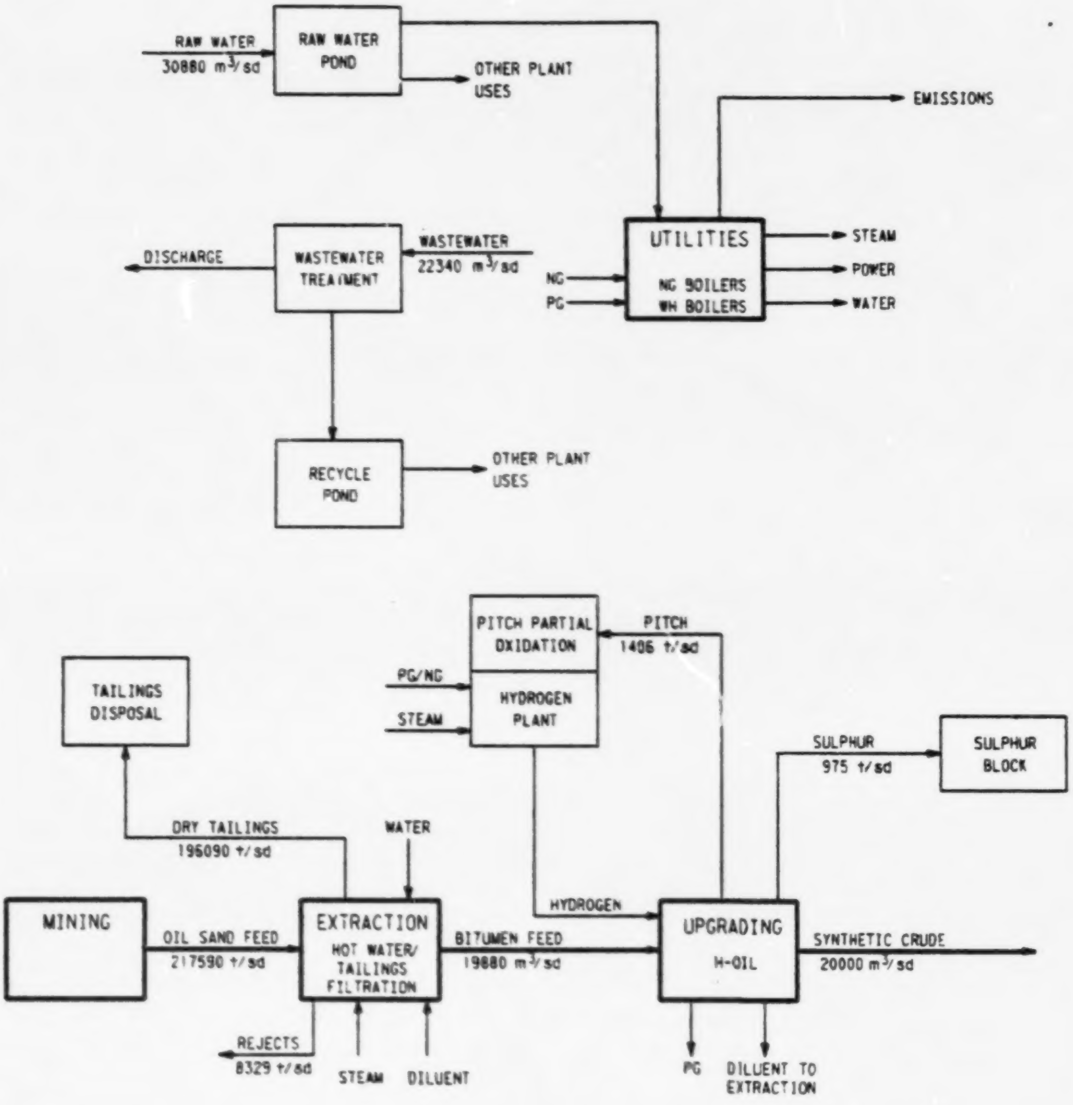
TABLE 2-6

Option Description - Option 5

	HOT WATER EXTRACTION/TAILINGS FILTRATION/ H-OIL/PARTIAL OXIDATION OF PITCH	
MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers	
	Oil Sands Mined	365145 t/sd
EXTRACTION	Hot Water Extraction with Tailings Filtration	
	Oil Sands Feed to Extraction	217590 t/sd
	Bitumen Feed to Extraction	24215 m^3/sd
UPGRADING	H-Oil with Partial Oxidation of Pitch (Hydrogen Production)	
	Bitumen Feed to Upgrading	19880 m^3/sd
	Synthetic Crude Production	20000 m^3/sd
	Process Gas Production	73800 m^3/hr
	Pitch Production	1406 t/sd
	Sulphur Production	975 t/sd
UTILITIES		
	Steam: NG Boilers	94000 m^3/hr NG
	WH Boilers	660000 m^3/hr WH + 3900 m^3/hr NG
	Superheaters	4800 m^3/hr NG
	Power: Gas, Back Pressure and Steam Turbines	

WH Waste Heat from Gas Turbines
NG Natural Gas

BLOCK FLOW DIAGRAM


RAW WATER
30880 m³/sd
RAW WATER POND
OTHER PLANT USES
EMISSIONS
DISCHARGE
WASTEWATER TREATMENT
WASTEWATER
22340 m³/sd
UTILITIES
NG BOILERS
WH BOILERS
NG
PG
STEAM
POWER
WATER
RECYCLE POND
OTHER PLANT USES
PITCH PARTIAL OXIDATION
PITCH
1406 t/sd
TAILINGS DISPOSAL
PG/NG
STEAM
HYDROGEN PLANT
SULPHUR
975 t/sd
SULPHUR BLOCK
DRY TAILINGS
196090 t/sd
WATER
HYDROGEN
MINING
OIL SAND FEED
217590 t/sd
EXTRACTION
HOT WATER/ TAILINGS FILTRATION
BITUMEN FEED
19880 m³/sd
UPGRADING
H-OIL
SYNTHETIC CRUDE
20000 m³/sd
REJECTS
8329 t/sd
STEAM
DILUENT
PG
DILUENT TO EXTRACTION

PG - PROCESS GAS
NG - NATURAL GAS
WH - WASTE HEAT

FIGURE 2-15

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION 5 HOT WATER EXTRACTION/TAILINGS
FILTRATION/H-OIL/
PARTIAL OXIDATION OF PITCH

MONENCO CONSULTANTS LIMITED

TABLE 2-7

Option Description - Option 6

HOT WATER EXTRACTION/CANMET/PITCH BOILERS (FBC)			
MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers		
	Oil Sands Mined		345310 t/sd
EXTRACTION	Hot Water Extraction		
	Oil Sands Feed to Extraction		205770 t/sd
	Bitumen Feed to Extraction		22840 m^3/sd
UPGRADING	CANMET		
	Bitumen Feed to Upgrading		18840 m^3/sd
	Synthetic Crude Production		20000 m^3/sd
	Process Gas Production		53360 m^3/hr
	Pitch Production		1176 t/sd
	Sulphur Production		850 t/sd
UTILITIES			
	Steam:	Pitch Boilers (FBC)	49070 kg/hr Pitch
		WH Boilers	303000 m^3/hr WH + 2200 m^3/hr NG
		NG Boilers	48000 m^3/hr NG
		Superheaters	8700 m^3/hr NG
	Power:	Gas, Back Pressure and Steam Turbines	

WH Waste Heat from Gas Turbines
NG Natural Gas

BLOCK FLOW DIAGRAM

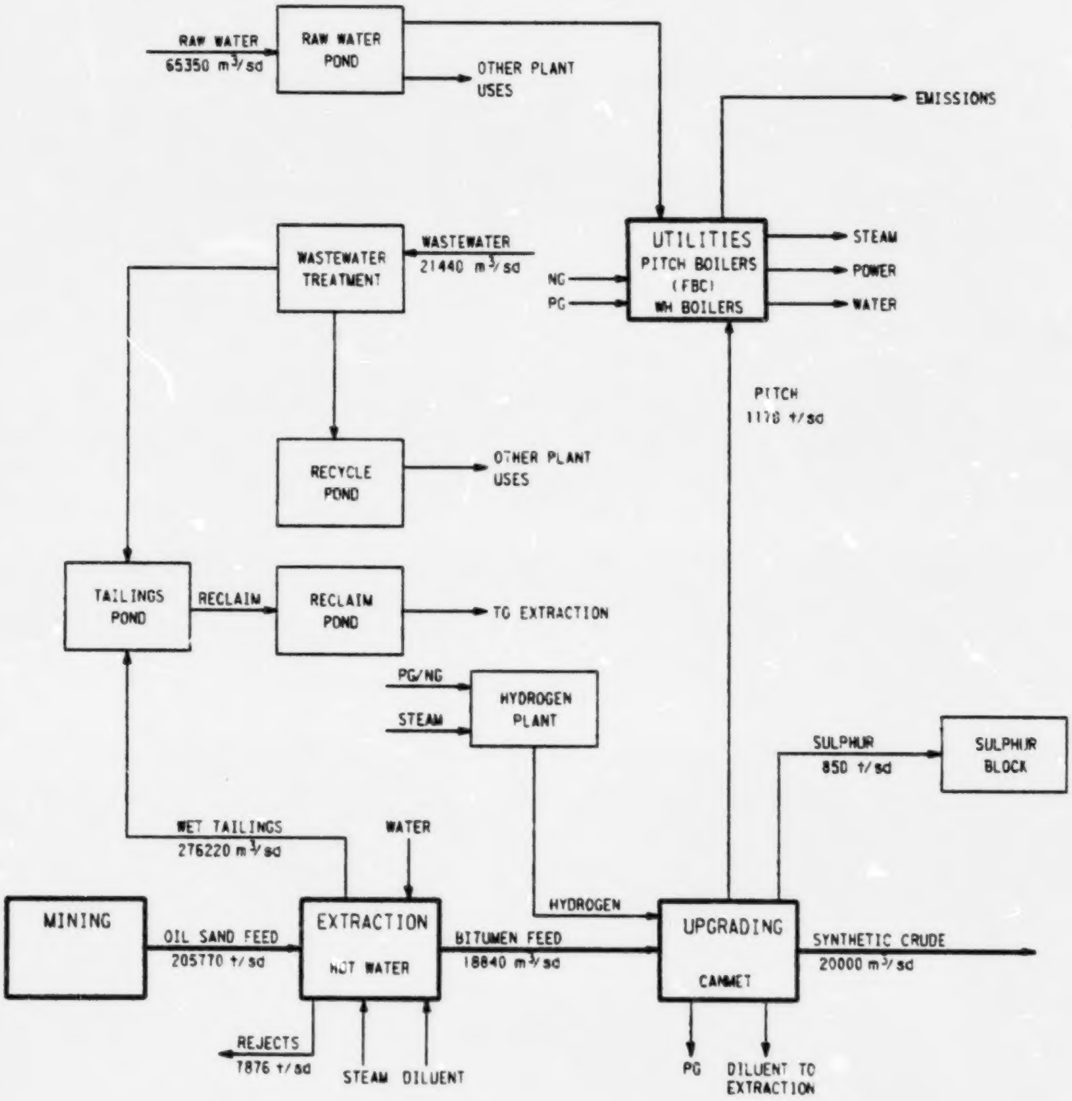

RAW WATER
65350 m³/sd
RAW WATER POND
OTHER PLANT USES
EMISSIONS
WASTEWATER
21440 m³/sd
WASTEWATER TREATMENT
NG
PG
UTILITIES
PITCH BOILERS
(FBC)
WH BOILERS
STEAM
POWER
WATER
PITCH
1178 t/sd
RECYCLE POND
OTHER PLANT USES
TAILINGS POND
RECLAIM
RECLAIM POND
TO EXTRACTION
PG/NG
STEAM
HYDROGEN PLANT
SULPHUR
850 t/sd
SULPHUR BLOCK
WET TAILINGS
276220 m³/sd
WATER
HYDROGEN
MINING
OIL SAND FEED
205770 t/sd
EXTRACTION
HOT WATER
BITUMEN FEED
18840 m³/sd
UPGRADING
CANMET
SYNTHETIC CRUDE
20000 m³/sd
REJECTS
7876 t/sd
STEAM
DILUENT
PG
DILUENT TO EXTRACTION

FIGURE 2-16

PG - PROCESS GAS
NG - NATURAL GAS
WH - WASTE HEAT

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 6 HOT WATER EXTRACTION/CANMET/
PITCH BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

TABLE 2-8

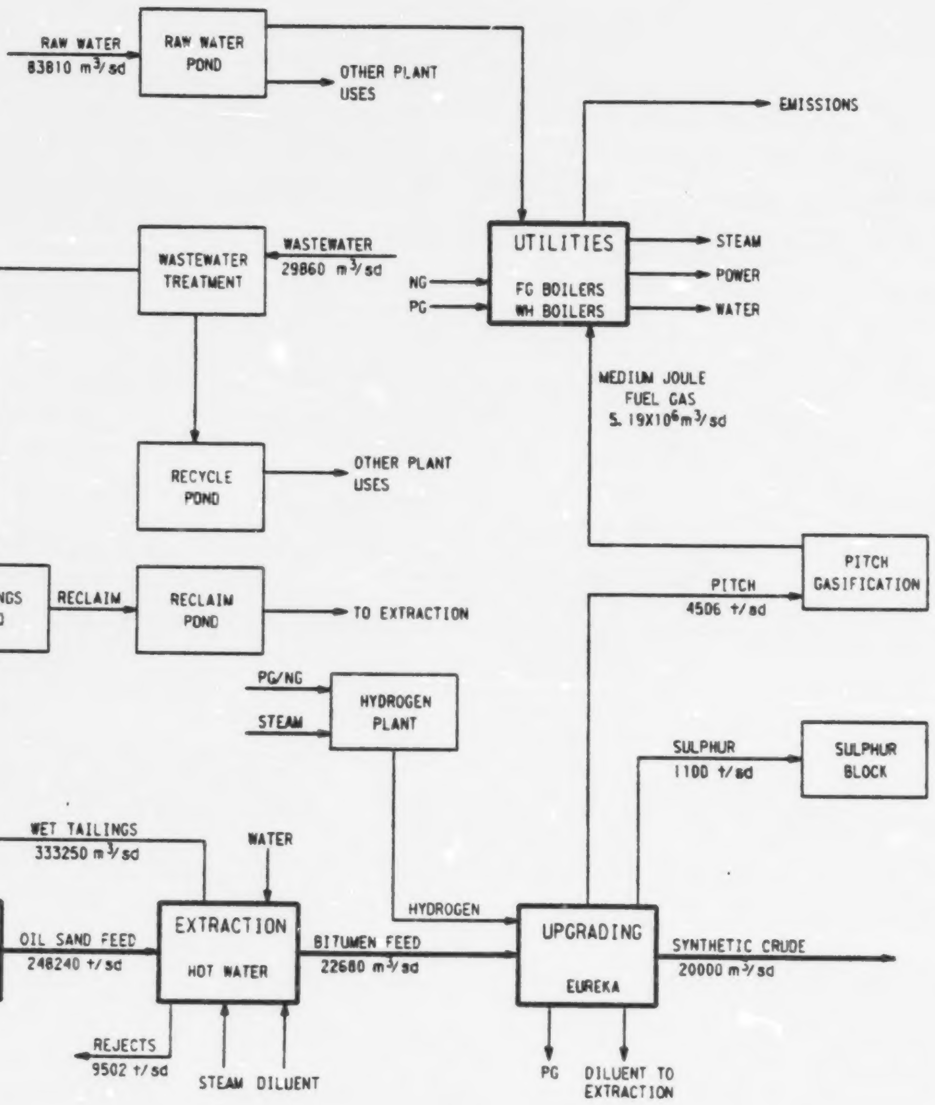
Option Description - Option 7

	HOT WATER EXTRACTION/EUREKA/GASIFICATION OF PITCH	
MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers	
	Oil Sands Mined	416575 t/sd
EXTRACTION	Hot Water Extraction	
	Oil Sands Feed to Extraction	248240 t/sd
	Bitumen Feed to Extraction	27555 m^3/sd
UPGRADING	Eureka with Pitch Gasification	
	Bitumen Feed to Upgrading	22680 m^3/sd
	Synthetic Crude Production	20000 m^3/sd
	Process Gas Production	45680 m^3/hr
	Medium Joule Fuel Gas Production	269200 m^3/hr
	Sulphur Production	1100 t/sd
UTILITIES		
	Steam: FG Boilers	216200 m^3/hr FG
	WH Boilers	1508000 m^3/hr WH + 7000 m^3/hr NG
	Superheaters	53000 m^3/hr FG
	Power: Gas, Back Pressure and Steam Turbines	

FG Medium Joule Fuel Gas from Pitch Gasification
WH Waste Heat from Gas Turbines
NG Natural Gas

MONENCO CONSULTANTS LIMITED

BLOCK FLOW DIAGRAM



RAW WATER
83810 m³/sd
RAW WATER POND
OTHER PLANT USES
EMISSIONS
WASTEWATER TREATMENT
WASTEWATER
29860 m³/sd
NG
PG
UTILITIES
FG BOILERS
WH BOILERS
STEAM
POWER
WATER
MEDIUM JOULE FUEL GAS
5.19X10⁶ m³/sd
RECYCLE POND
OTHER PLANT USES
PITCH GASIFICATION
PITCH
4506 t/sd
TAILINGS POND
RECLAIM
RECLAIM POND
TO EXTRACTION
PG/NG
STEAM
HYDROGEN PLANT
SULPHUR
1100 t/sd
SULPHUR BLOCK
WET TAILINGS
333250 m³/sd
WATER
HYDROGEN
MINING
OIL SAND FEED
248240 t/sd
EXTRACTION
HOT WATER
BITUMEN FEED
22680 m³/sd
UPGRADING
EUREKA
SYNTHETIC CRUDE
20000 m³/sd
REJECTS
9502 t/sd
STEAM
DILUENT
PG
DILUENT TO EXTRACTION

FIGURE 2-17

PG - PROCESS GAS
NG - NATURAL GAS
FG - MEDIUM JOULE FUEL GAS
WH - WASTE HEAT

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION 7 HOT WATER EXTRACTION/EUREKA
GASIFICATION OF PITCH
MONENCO CONSULTANTS LIMITED

TABLE 2-9

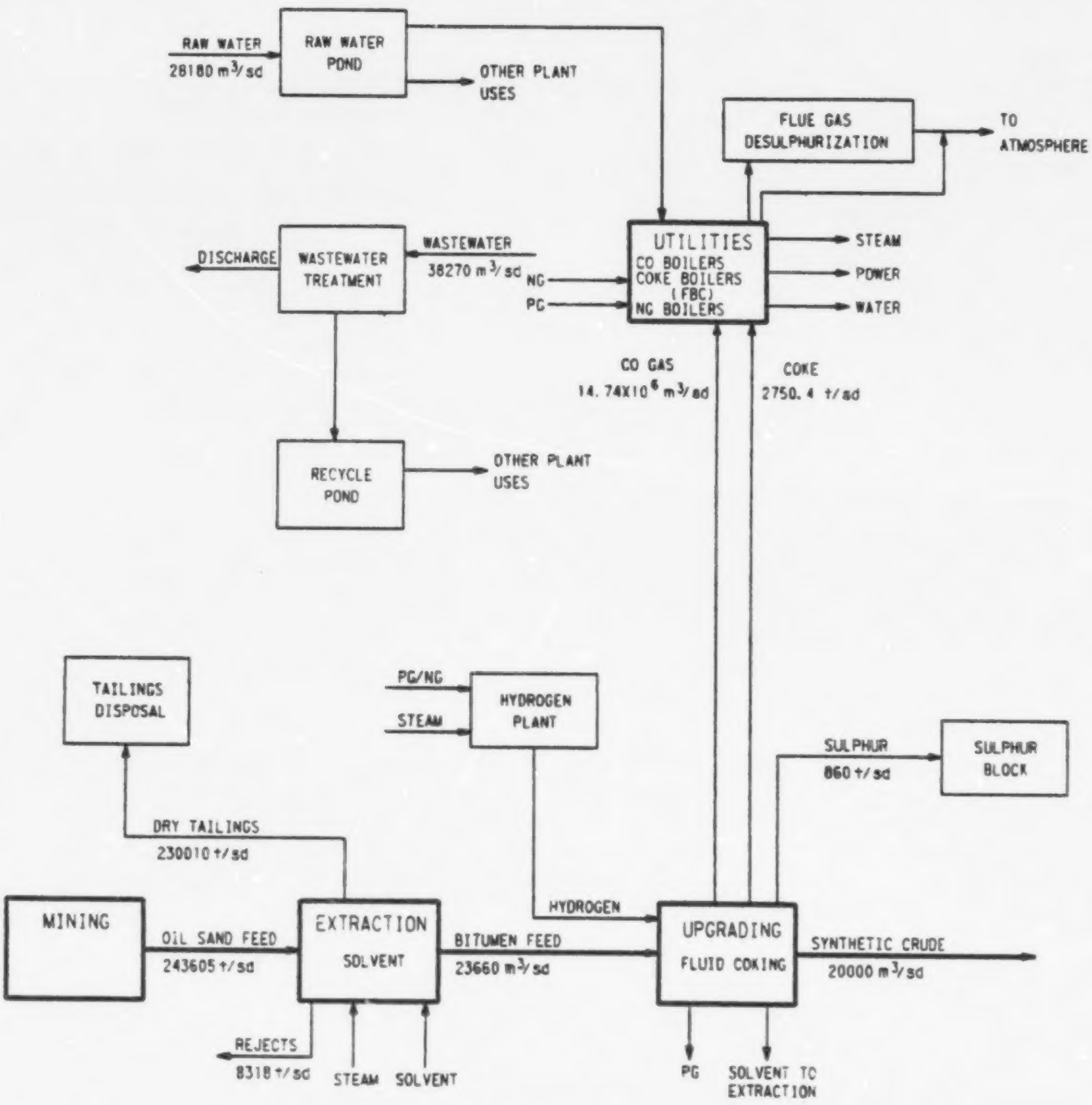
Option Description - Option 8

SOLVENT EXTRACTION/FLUID COKING/CO BOILERS/COKE BOILERS (FBC)		
MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers	
	Oil Sands Mined	409420 t/sd
EXTRACTION	Solvent Extraction	
	Oil Sands Feed to Extraction	243600 t/sd
	Bitumen Feed to Extraction	27040 m^3/sd
UPGRADING	Fluid Coking	
	Bitumen Feed to Upgrading	23660 m^3/sd
	Synthetic Crude Production	20000 m^3/sd
	Process Gas Production	102680 m^3/hr
	Coke Production	2750 t/sd
	Sulphur Production	860 t/sd
UTILITIES	Steam: CO Boilers + FGD	614000 m^3/hr CO + 7800 m^3/hr PG
	Coke Boilers (FBC)	114600 kg/hr
	NG Boilers	19000 m^3/hr
	Superheaters	6600 m^3/hr NG + 2100 m^3/hr PG
	Power: Back Pressure and Steam Turbines	

CO Coke Gas from Fluid Coking
PG Process Gas
NG Natural Gas

MONENCO CONSULTANTS LIMITED

BLOCK FLOW DIAGRAM


RAW WATER
28180 m³/sd
RAW WATER POND
OTHER PLANT USES
FLUE GAS DESULPHURIZATION
TO ATMOSPHERE
DISCHARGE
WASTEWATER TREATMENT
WASTEWATER
38270 m³/sd
NG
PG
UTILITIES
CO BOILERS
COKE BOILERS (FBC)
NG BOILERS
STEAM
POWER
WATER
CO GAS
14.74X10⁶ m³/sd
COKE
2750.4 t/sd
RECYCLE POND
OTHER PLANT USES
TAILINGS DISPOSAL
PG/NG
STEAM
HYDROGEN PLANT
SULPHUR
860 t/sd
SULPHUR BLOCK
DRY TAILINGS
230010 t/sd
HYDROGEN
MINING
OIL SAND FEED
243605 t/sd
EXTRACTION
SOLVENT
BITUMEN FEED
23660 m³/sd
UPGRADING
FLUID COKING
SYNTHETIC CRUDE
20000 m³/sd
REJECTS
8318 t/sd
STEAM
SOLVENT
PG
SOLVENT TO EXTRACTION

PG - PROCESS GAS

NG - NATURAL GAS

FIGURE 2-18

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 8 SOLVENT EXTRACTION/FLUID COKING/
CO BOILERS/COKE BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

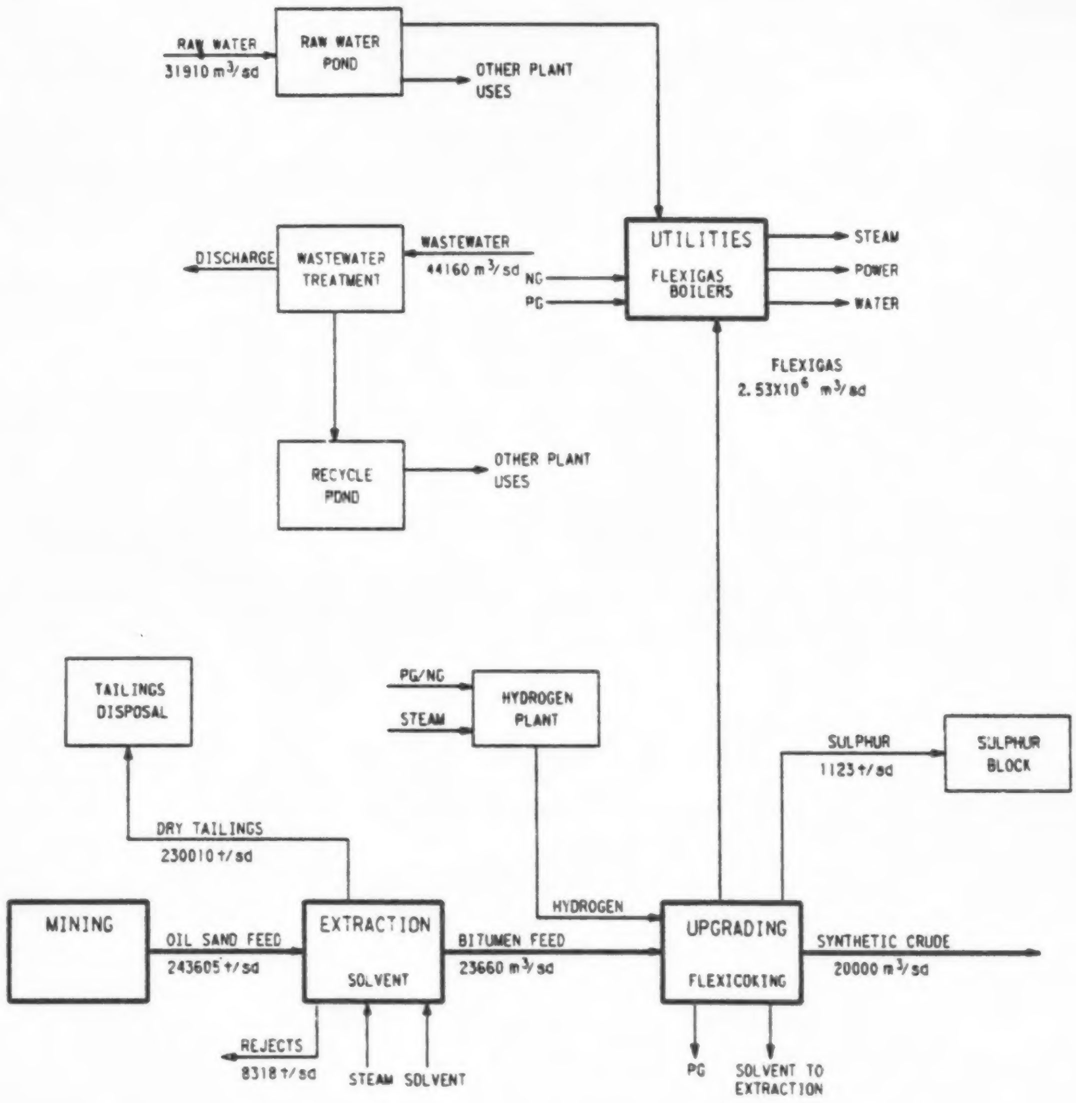
TABLE 2-10

Option Description - Option 9

SOLVENT EXTRACTION/FLEXICOKING/FLEXIGAS BOILERS		
MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers	
	Oil Sands Mined	409420 t/sd
EXTRACTION	Solvent Extraction	
	Oil Sands Feed to Extraction	243600 t/sd
	Bitumen Feed to Extraction	27040 m^3/sd
UPGRADING	Flexicoking	
	Bitumen Feed to Upgrading	23660 m^3/sd
	Synthetic Crude Production	20000 m^3/sd
	Process Gas Production	102680 m^3/hr
	Flexigas Production	865000 m^3/hr
	Sulphur Production	1123 t/sd
UTILITIES	Steam: Flexigas Boilers 865000 m^3/hr Flexigas + 105500 m^3/hr NG	
	Power: Back Pressure and Steam Turbines	

Flexigas	Low Joule Fuel Gas from Flexicoking Gasifier
NG	Natural Gas

BLOCK FLOW DIAGRAM


RAW WATER
31910 m³/sd
RAW WATER POND
OTHER PLANT USES
UTILITIES
FLEXIGAS BOILERS
STEAM
POWER
WATER
NG
PG
WASTEWATER
44160 m³/sd
WASTEWATER TREATMENT
DISCHARGE
RECYCLE POND
OTHER PLANT USES
FLEXIGAS
2.53X10⁶ m³/sd
TAILINGS DISPOSAL
PG/NG
STEAM
HYDROGEN PLANT
SULPHUR
1123 t/sd
SULPHUR BLOCK
DRY TAILINGS
230010 t/sd
HYDROGEN
MINING
OIL SAND FEED
243605 t/sd
EXTRACTION
SOLVENT
BITUMEN FEED
23660 m³/sd
UPGRADING
FLEXICOKING
SYNTHETIC CRUDE
20000 m³/sd
REJECTS
8318 t/sd
STEAM
SOLVENT
PG
SOLVENT TO EXTRACTION

PG - PROCESS GAS

NG - NATURAL GAS

FIGURE 2-19

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS FROM A MINING OIL SANDS COMPLEX

OPTION 9 SOLVENT EXTRACTION/FLEXICOKING/FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED

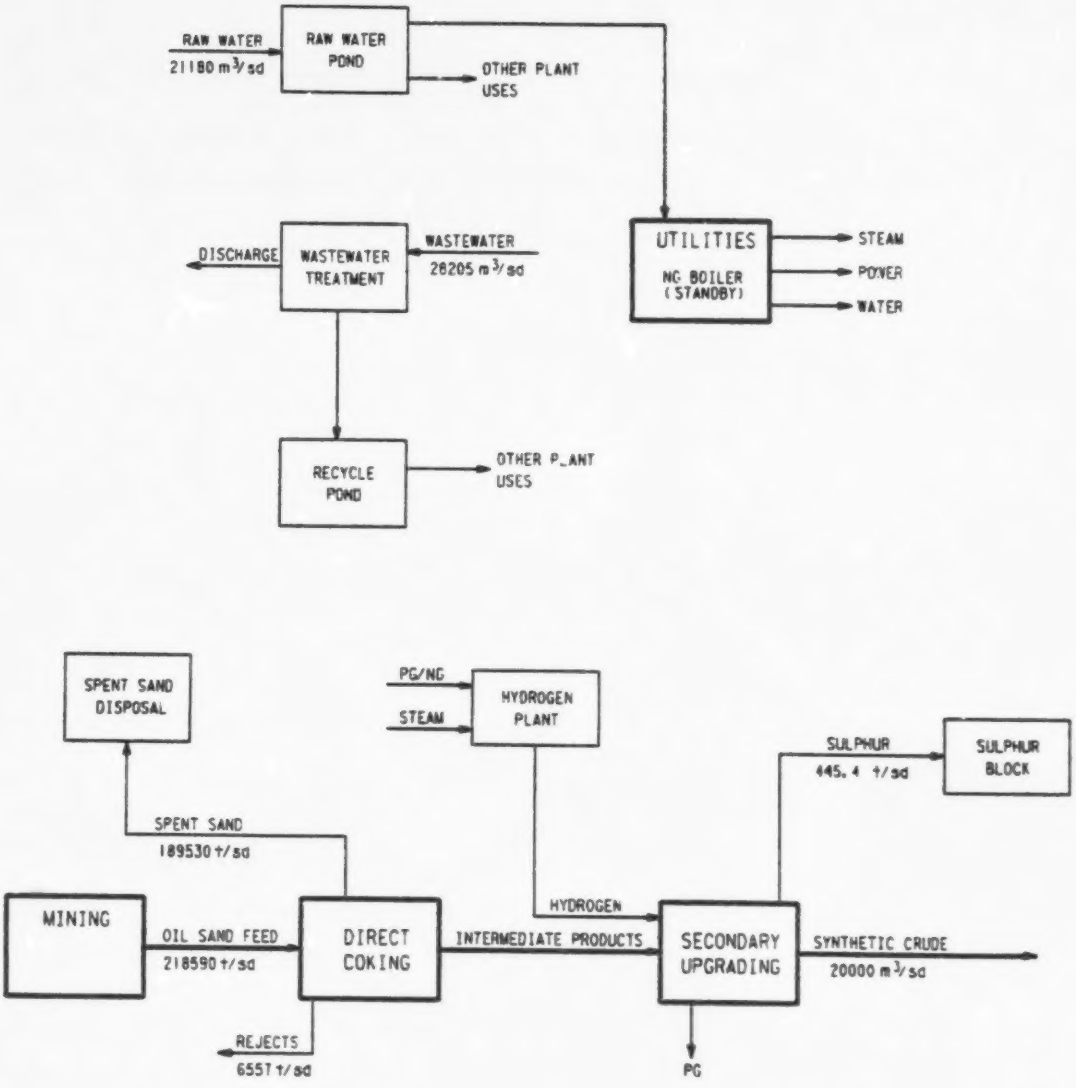
TABLE 2-11

Option Description - Option 10

DIRECT COKING		
MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers	
	Oil Sands Mined	385485 t/sd
EXTRACTION/ PRIMARY UPGRADING	Direct Coking	
	Oil Sands Feed to Direct Coking	218440 t/sd
	Bitumen Feed to Direct Coking	24250 m^3/sd
SECONDARY UPGRADING		
	Synthetic Crude Production	20000 m^3/sd
	Process Gas Production	29300 m^3/hr
	Sulphur Production	445 t/sd
UTILITIES		
	Steam: By Waste Heat Utilization in Direct Coking	
	Superheaters	7100 m^3/hr NG
	Power: Back Pressure and Steam Turbines	

NG Natural Gas

BLOCK FLOW DIAGRAM


RAW WATER
21180 m³/sd
RAW WATER POND
OTHER PLANT USES
UTILITIES
NG BOILER (STANDBY)
STEAM
POWER
WATER
DISCHARGE
WASTEWATER TREATMENT
WASTEWATER
28205 m³/sd
RECYCLE POND
OTHER PLANT USES
SPENT SAND DISPOSAL
PG/NG
STEAM
HYDROGEN PLANT
SULPHUR
445.4 t/sd
SULPHUR BLOCK
SPENT SAND
189530 t/sd
HYDROGEN
MINING
OIL SAND FEED
218590 t/sd
DIRECT COKING
INTERMEDIATE PRODUCTS
SECONDARY UPGRADING
SYNTHETIC CRUDE
20000 m³/sd
REJECTS
6557 t/sd
PG

PG - PROCESS GAS

NG - NATURAL GAS

FIGURE 2-20

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 10 DIRECT COKING

MONENCO CONSULTANTS LIMITED

TABLE 2-12

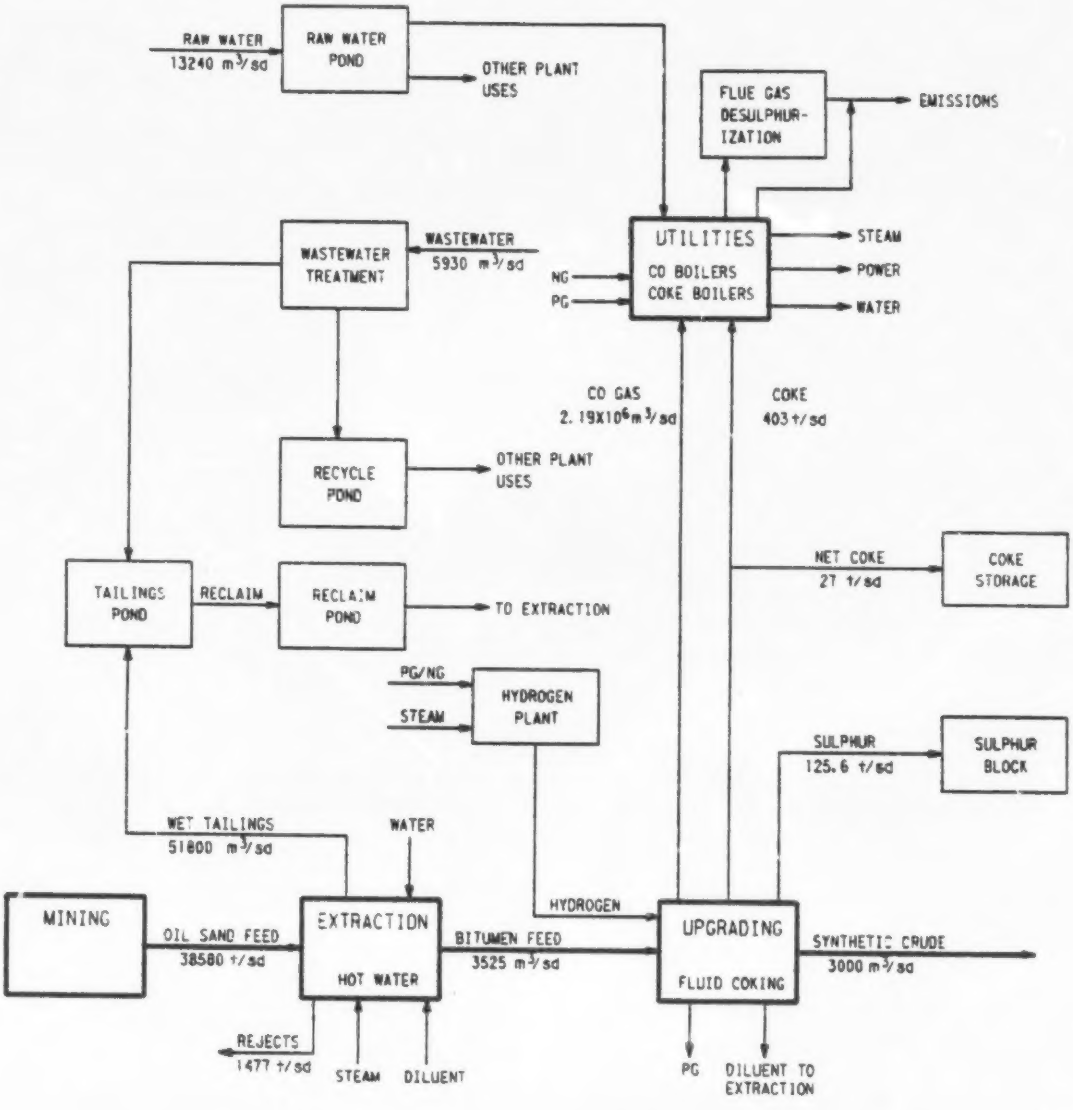
Option Description - Option 11

HOT WATER EXTRACTION/FLUID COKING/CO AND COKE BOILERS		
MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers	
	Oil Sands Mined	64750 t/sd
EXTRACTION	Hot Water Extraction	
	Oil Sands Feed to Extraction	38580 t/sd
	Bitumen Feed to Extraction	4275 m^3/sd
UPGRADING	Fluid Coking	
	Bitumen Feed to Upgrading	3525 m^3/sd
	Synthetic Crude Production	3000 m^3/sd
	Process Gas Production	15290 m^3/hr
	Coke Production	430 t/sd
	Sulphur Production	125.6 t/sd
UTILITIES		
	Steam: CO Boilers + FGD	91200 m^3/hr CO + 1200 m^3/hr PG
	Coke Boilers + FGD	16800 kg/hr Coke + 13500 m^3/hr PG
	Superheaters	1155 m^3/hr NG + 330 m^3/hr PG
	Power: Back Pressure and Steam Turbines	

CO Coke Gas from Fluid Coking
PG Process Gas
NG Natural Gas

MONENCO CONSULTANTS LIMITED

BLOCK FLOW DIAGRAM


RAW WATER
13240 m³/sd
RAW WATER POND
OTHER PLANT USES
FLUE GAS DESULPHURIZATION
EMISSIONS
WASTEWATER TREATMENT
WASTEWATER
5930 m³/sd
NG
PG
UTILITIES
CO BOILERS
COKE BOILERS
STEAM
POWER
WATER
CO GAS
2.19X10⁶ m³/sd
COKE
403 t/sd
RECYCLE POND
OTHER PLANT USES
NET COKE
27 t/sd
COKE STORAGE
TAILINGS POND
RECLAIM
RECLAIM POND
TO EXTRACTION
PG/NG
STEAM
HYDROGEN PLANT
SULPHUR
125.6 t/sd
SULPHUR BLOCK
WET TAILINGS
51800 m³/sd
WATER
HYDROGEN
MINING
OIL SAND FEED
38580 t/sd
EXTRACTION
HOT WATER
BITUMEN FEED
3525 m³/sd
UPGRADING
FLUID COKING
SYNTHETIC CRUDE
3000 m³/sd
REJECTS
1477 t/sd
STEAM
DILUENT
PG
DILUENT TO EXTRACTION

PG - PROCESS GAS

NG - NATURAL GAS

FIGURE 2-21

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 11 HOT WATER EXTRACTION/FLUID COKING/
CO & COKE BOILERS

MONENCO CONSULTANTS LIMITED

TABLE 2-13

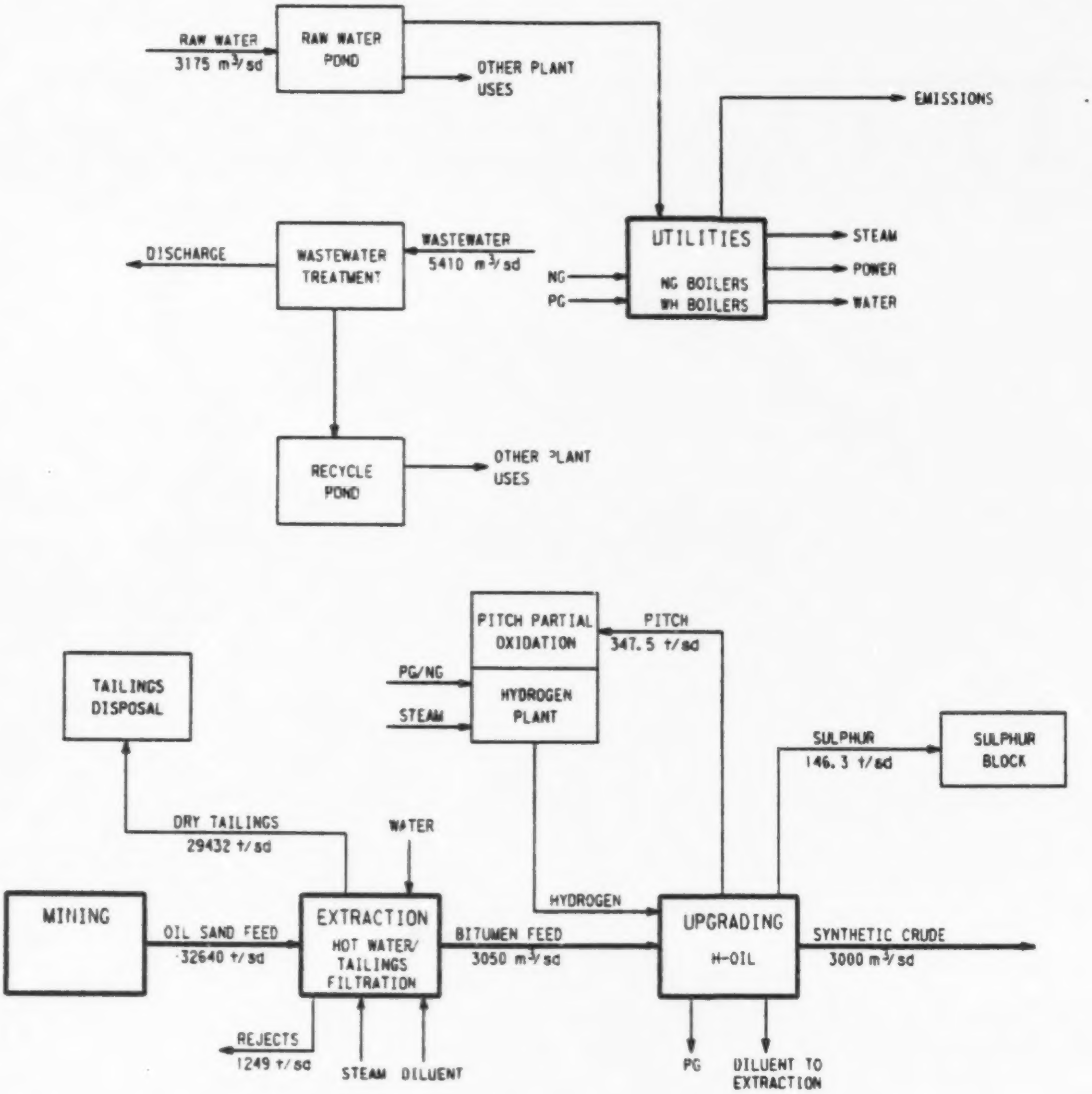
Option Description - Option 12

HOT WATER EXTRACTION/TAILINGS FILTRATION/ H-OIL/PARTIAL OXIDATION OF PITCH

MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers	
	Oil Sands Mined	54770 t/sd
EXTRACTION	Hot Water Extraction with Tailings Filtration	
	Oil Sands Feed to Extraction	32640 t/sd
	Bitumen Feed to Extraction	3625 m^3/sd
UPGRADING	H-Oil with Partial Oxidation Production)	
		m^3/sd
	Process Gas Production	11070 m^3/hr
	Pitch Production	211 t/sd
	Sulphur Production	150 t/sd
UTILITIES		
	Steam: NG Boilers	14100 m^3/hr NG
	WH Boilers	99000 m^3/hr WH + 590 m^3/hr NG
	Superheaters	720 m^3/hr NG
	Power: Gas, Back Pressure and Steam Turbines	

WH Waste Heat from Gas Turbines
NG Natural Gas

BLOCK FLOW DIAGRAM


RAW WATER
3175 m³/sd
RAW WATER POND
OTHER PLANT USES
EMISSIONS
UTILITIES
NG BOILERS
WH BOILERS
NG
PG
STEAM
POWER
WATER
DISCHARGE
WASTEWATER TREATMENT
WASTEWATER
5410 m³/sd
RECYCLE POND
OTHER PLANT USES
PITCH PARTIAL OXIDATION
PITCH
347.5 t/sd
PG/NG
STEAM
HYDROGEN PLANT
TAILINGS DISPOSAL
SULPHUR
146.3 t/sd
SULPHUR BLOCK
DRY TAILINGS
29432 t/sd
WATER
HYDROGEN
MINING
OIL SAND FEED
32640 t/sd
EXTRACTION
HOT WATER/ TAILINGS FILTRATION
BITUMEN FEED
3050 m³/sd
UPGRADING
H-OIL
SYNTHETIC CRUDE
3000 m³/sd
REJECTS
1249 t/sd
STEAM
DILUENT
PG
DILUENT TO EXTRACTION

PG - PROCESS GAS
NG - NATURAL GAS
WH - WASTE HEAT

FIGURE 2-22

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION 12 HOT WATER EXTRACTION/TAILINGS
FILTRATION/H-OIL/
PARTIAL OXIDATION OF PITCH

MONENCO CONSULTANTS LIMITED

TABLE 2-14

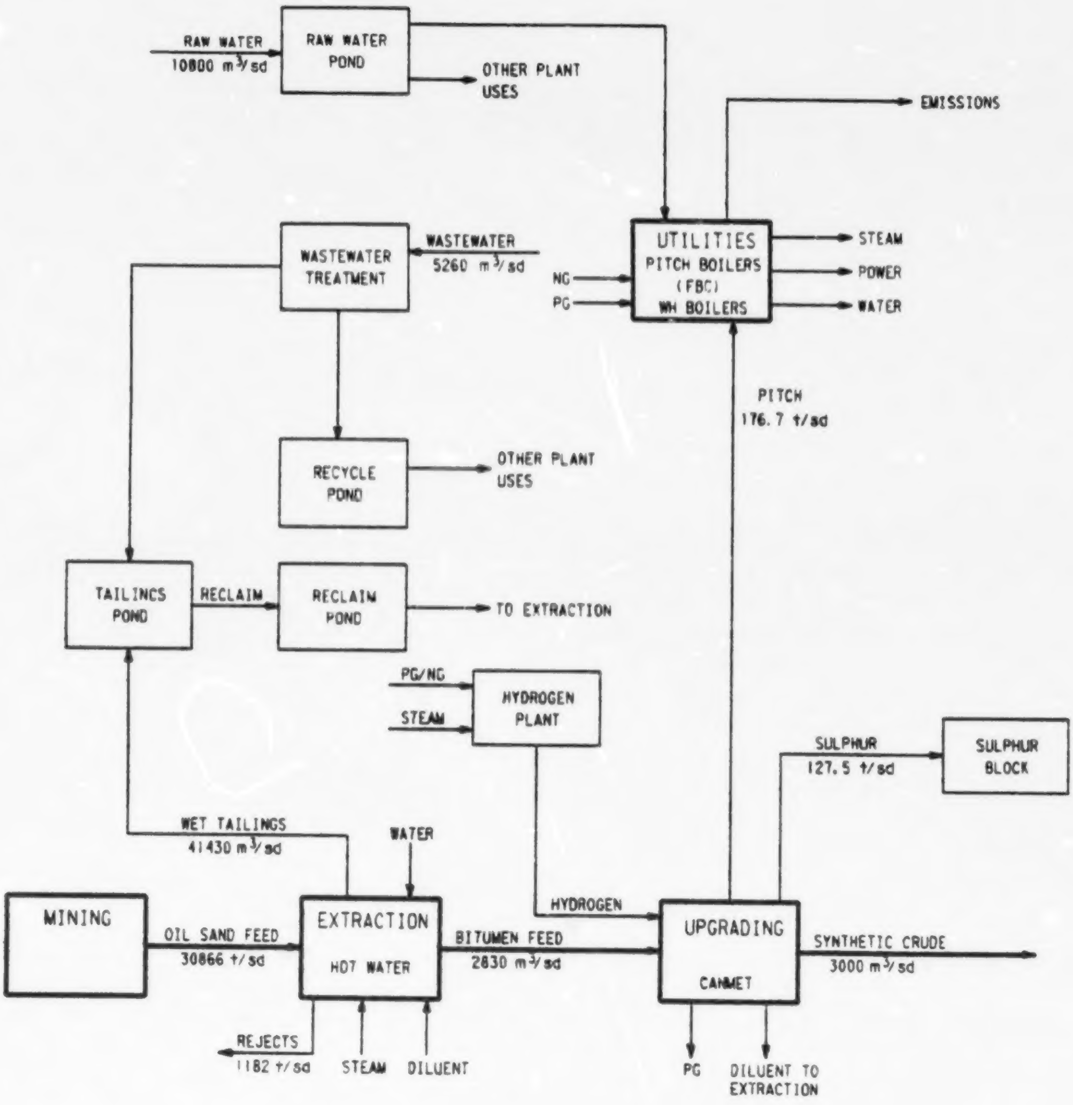
Option Description - Option 13

HOT WATER EXTRACTION/CANMET/PITCH BOILERS (FBC)

MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers	
	Oil Sands Mined	51800 t/sd
EXTRACTION	Hot Water Extraction	
	Oil Sands Feed to Extraction	30865 t/sd
	Bitumen Feed to Extraction	3425 m^3/sd
UPGRADING	CANMET	
	Bitumen Feed to Upgrading	2825 m^3/sd
	Synthetic Crude Production	20000 m^3/sd
	Process Gas Production	8000 m^3/hr
	Pitch Production	176 t/sd
	Sulphur Production	127.5 t/sd
UTILITIES		
	Steam: Pitch Boilers (FBC)	7360 kg/hr Pitch
	WH Boilers	45450 m^3/hr WH + 330 m^3/hr NG
	NG Boilers	7200 m^3/hr NG
	Superheaters	1305 m^3/hr NG
	Power: Gas, Back Pressure and Steam Turbines	

WH Waste Heat from Gas Turbines
NG Natural Gas

BLOCK FLOW DIAGRAM


RAW WATER
10800 m^3/sd
RAW WATER POND
OTHER PLANT USES
EMISSIONS
WASTEWATER TREATMENT
WASTEWATER
5260 m^3/sd
NG
PG
UTILITIES
PITCH BOILERS
(FBC)
WH BOILERS
STEAM
POWER
WATER
PITCH
176.7 t/sd
RECYCLE POND
OTHER PLANT USES
TAILINGS POND
RECLAIM
RECLAIM POND
TO EXTRACTION
PG/NG
STEAM
HYDROGEN PLANT
SULPHUR
127.5 t/sd
SULPHUR BLOCK
WET TAILINGS
41430 m^3/sd
WATER
HYDROGEN
MINING
OIL SAND FEED
30866 t/sd
EXTRACTION
HOT WATER
BITUMEN FEED
2830 m^3/sd
UPGRADING
CANMET
SYNTHETIC CRUDE
3000 m^3/sd
REJECTS
1182 t/sd
STEAM
DILUENT
PG
DILUENT TO EXTRACTION

PG - PROCESS GAS
NG - NATURAL GAS
WH - WASTE HEAT

FIGURE 2-23

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 13 HOT WATER EXTRACTION/CANMET/
PITCH BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

TABLE 2-15

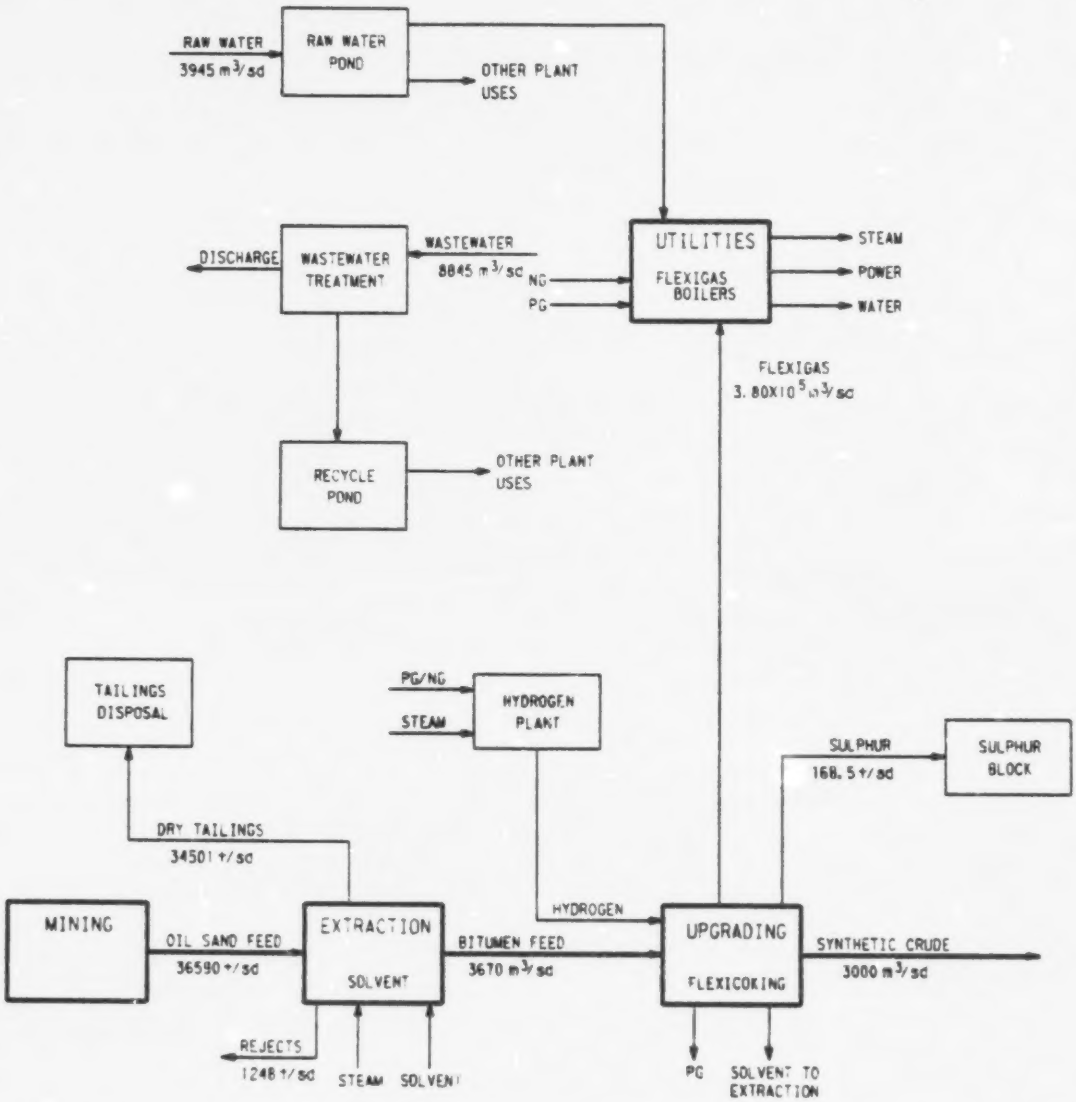
Option Description - Option 14

SOLVENT EXTRACTION/FLEXICOKING/FLEXIGAS BOILERS

MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers	
	Oil Sands Mined	61415 t/sd
EXTRACTION	Solvent Extraction	
	Oil Sands Feed to Extraction	36540 t/sd
	Bitumen Feed to Extraction	4055 m^3/sd
UPGRADING	Flexicoking	
	Bitumen Feed to Upgrading	3550 m^3/sd
	Synthetic Crude Production	3000 m^3/sd
	Process Gas Production	15400 m^3/hr
	Flexigas Production	129750 m^3/hr
	Sulphur Production	174 t/sd
UTILITIES	Steam: Flexigas Boilers 129750 m^3/hr Flexigas + 15825 m^3/hr NG	
	Power: Back Pressure and Steam Turbines	

Flexigas	Low Joule Fuel Gas from Flexicoking Gasifier
NG	Natural Gas

BLOCK FLOW DIAGRAM


RAW WATER
3945 m3/sd
RAW WATER POND
OTHER PLANT USES
UTILITIES
FLEXIGAS BOILERS
STEAM
POWER
WATER
NG
PG
WASTEWATER
8845 m3/sd
DISCHARGE
WASTEWATER TREATMENT
FLEXIGAS
3.80X10^5 m3/sd
RECYCLE POND
OTHER PLANT USES
TAILINGS DISPOSAL
PG/NG
STEAM
HYDROGEN PLANT
SULPHUR
168.5 t/sd
SULPHUR BLOCK
DRY TAILINGS
34501 t/sd
HYDROGEN
MINING
OIL SAND FEED
36590 t/sd
EXTRACTION
SOLVENT
BITUMEN FEED
3670 m3/sd
UPGRADING
FLEXICOKING
SYNTHETIC CRUDE
3000 m3/sd
REJECTS
1248 t/sd
STEAM
SOLVENT
PG
SOLVENT TO EXTRACTION

PG - PROCESS GAS

NG - NATURAL GAS

FIGURE 2-24

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 14 SOLVENT EXTRACTION/FLEXICOKING/
FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED

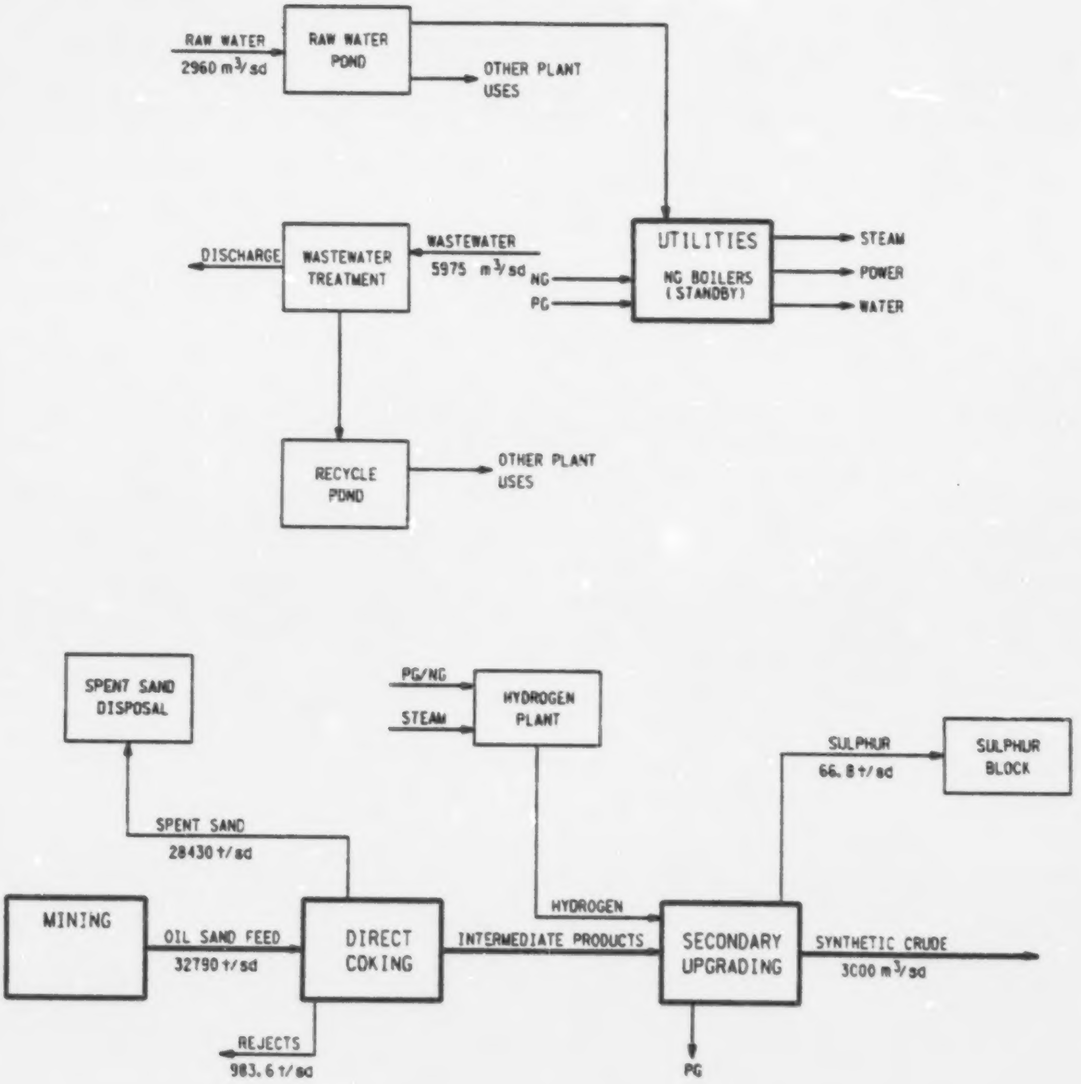
TABLE 2-16

Option Description - Option 15

	DIRECT COKING	
MINING	Bucketwheel Excavators and Draglines with Bucketwheel Reclaimers	
	Oil Sands Mined	57825 t/sd
EXTRACTION/ PRIMARY UPGRADING	Direct Coking	
	Oil Sands Feed to Direct Coking	32770 t/sd
	Bitumen Feed to Direct Coking	3640 m^3/sd
SECONDARY UPGRADING	Synthetic Crude Production	3000 m^3/sd
	Process Gas Production	4400 m^3/hr
	Sulphur Production	67 t/sd
UTILITIES	Steam: by Waste Heat Utilization in Direct Coking	
	Superheaters	1070 m^3/hr NG
	Power: Back Pressure and Steam Turbines	

NG Natural Gas

BLOCK FLOW DIAGRAM


RAW WATER
2960 m³/sd
RAW WATER POND
OTHER PLANT USES
DISCHARGE
WASTEWATER TREATMENT
WASTEWATER
5975 m³/sd
NG
PG
UTILITIES
NG BOILERS (STANDBY)
STEAM
POWER
WATER
RECYCLE POND
OTHER PLANT USES
SPENT SAND DISPOSAL
PG/NG
STEAM
HYDROGEN PLANT
SULPHUR
66.8 t/sd
SULPHUR BLOCK
SPENT SAND
28430 t/sd
HYDROGEN
MINING
OIL SAND FEED
32790 t/sd
DIRECT COKING
INTERMEDIATE PRODUCTS
SECONDARY UPGRADING
SYNTHETIC CRUDE
3000 m³/sd
REJECTS
983.6 t/sd
PG

PG - PROCESS GAS
NG - NATURAL GAS

FIGURE 2-25

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION 15 DIRECT COKING
MONENCO CONSULTANTS LIMITED

PART 3

WASTE STREAM IDENTIFICATION AND CHARACTERIZATION

PART 3 - WASTE STREAM IDENTIFICATION AND CHARACTERIZATION

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3.1 INTRODUCTION

The major gaseous, liquid and solid emissions from each of the selected oil sands options are a function of the extraction plant and the upgrading facility. In order to identify and quantify these emissions, the bitumen conversion efficiencies of upgrading and bitumen recovery efficiencies of the extraction plant (Section 5.1) were applied to the fixed synthetic crude production rate to determine the capacities of each unit process. Waste stream flow rates were then prorated from reported rates in the literature. For those processes which were not sufficiently defined in the literature, waste stream data were obtained directly from the process licensors.

Emissions characterization data for mining and utilities, and for the supportive unit processes in offsites, were obtained from three sources as follows:

1. in-house data (water treatment plant effluents, sewage treatment plant effluents, runoff, mine water, etc.);
2. combustion calculations (combustion of natural gas, process gas, fuel gas and residuals to generate the steam requirements of each selected option); and
3. analyses of similar unit processes (i.e. the application of waste stream data from coal gasification to coke or pitch gasification).

Each waste stream is described briefly in Section 3.3, Waste Stream Identification. Significant assumptions used to determine the composition or flow rates of the waste streams are identified in this section. For each of the waste streams, a service factor has been determined from literature sources and in-house information. The service factor for industrial process components is a measure of the continuity of an operation and is expressed as the ratio of the actual running time to calendar days (includes both scheduled and unscheduled downtime). For non-process waste streams, the service factor has been determined from the period of time an activity or event occurs. For example, since runoff is expected to occur only over the non-frozen months (214 days per year), the service factor for runoff-related waste streams is 214/365, or 0.586.

The service factor is provided to enable calculation of annual emissions or determination of a calendar day flow rate. For example, a waste stream may have a stream day (sd) flow rate of 1000 m^3/sd with a service factor of 0.875. The calendar day (cd) flow rate and annual emissions are computed as follows:

calendar day flow rate = 1000 x 0.875 = 875 m^3/cd
annual emissions = 875 x 365 = 319 375 m^3/yr

Waste stream characterization data are presented in Section 3.4, Waste Stream Characterization. The method of data presentation has been selected to provide the complete process-related information in logical and functional format, to afford maximum utilization of the computerized data storage and the computer assisted drafting system, and to provide data which may be readily used. The data are presented on pollutant flow diagrams and waste management matrices. The composition of each waste stream is presented in matrix format on the waste management matrices. The pollutant flow diagrams identify the source and disposition of each waste stream, provide a conceptual plan for waste collection and distribution, quantify the waste stream emission rates and identify the wastewater treatment scheme.

3.2 DATA BASE

Waste stream flow rates and composition data have been assembled from an extensive search of the literature and from process licensors. As indicated previously, this data base was supplemented with in-house information. In many cases it was necessary to prorate reported waste stream flow rates and amend waste stream compositions so that the data would reflect the base conditions established for this study (oil sands composition, bitumen sulphur content, production rates, etc). Where more than one source of waste management information was available, an analysis of the data was undertaken to establish an appropriate flow rate and to average or combine waste stream characterization parameters in order to establish as complete a composition as possible.

Waste stream data from operational plants was not used directly in the development of the data base. However, available operations data was included in the aforementioned data analysis program. With some exceptions, it was found that the operational data did not apply to the oil sands and bitumen qualities established for this study, details of unit processes were not the same as unit processes included in the selected options, or waste stream data frequently was a combination of streams from more than one process.

The waste management data base is suitable for use in oil sands process evaluations at the conceptual engineering stage. At this stage of a project, the waste management data would be reviewed in light of project conditions and updated where necessary, much in the same manner as product stream throughputs and composition are analysed.

The waste characterization data base is not to be considered complete as there are significant gaps in the areas of characterizing trace elements and trace organics in plant emissions. In addition, the constituents of the total organics in liquid and solid waste streams are not identified. These gaps are primarily attributable to the secondary importance given to the gathering of waste management data in laboratory studies and pilot and full scale plant analyses.

With respect to trace organics, a number of studies of wastewaters from refineries, including an oil sands complex, gas processing plants and other hydrocarbon processing industries have been completed. These studies indicate that wastewater emissions from an oil sands complex could contain the following EPA priority pollutants:

Volatile Compounds
  Benzene
  Carbon Tetrachloride
  Chloroform
  Ethylbenzene
  Methylene Chloride
  Toluene
  Trichlorofluoromethane

Base Neutral Compounds
  Bis (2-ethylhexyl) phthalate
  Diethylphlhalate

Acid Extractable Compounds
  2, 4 Dimethylphenol
  Phenol

In addition, wastewaters could contain the following:

paraffins and olefins
cyclic paraffins
alcohols
substituted benzenes
polycyclic aromatic hydrocarbons
benzothiophenes

The concentrations of these trace organics would probably be in the parts per billion range. However additional studies are required to confirm this and their exact form in plant emissions.

3.3 WASTE STREAM IDENTIFICATION

331 MINING

The oil sands mining operation has been described in detail in Part 2. Waste streams from mining are identified and briefly described in this section. A factor which affects the quantification and disposition of some of the waste streams, primarily solid wastes, is the presence of a tailings pond. A percentage of the overburden material excavated ahead of mining is utilized for dyke construction in the tailings pond options.

The assumed year of operation of the mine is year ten, at which time sufficient mined-out space exists for the establishment and operation of the in-pit tailings pond for the tailings pond options. During the earlier years of operation (up to year eight), tailings are disposed of in an external tailings pond located at grade. The space requirements for the in-pit tailings pond necessitate larger storage areas for muskeg and subsoil in earlier years. At year ten, however, all of the solids from the mining operation and solids from extraction, upgrading and utilities are directed to the mine for disposal.

.1 Site Preparation

Emissions — Service Factor 0.164

Clearing of trees and scrub from the mining area precedes the mining operation by five years. It is a task which takes place over two months in the winter and involves the selective removal of marketable timber. The remaining wood, assumed to be 60% of the total, is burned in the open, generating air emissions.

Ash — Service Factor 0.164

The residue remaining after open burning of the non-marketable timber is stripped with the muskeg in following years. The residue is 30% of the ash content of the wood.

.2 Dewatering

Surface Aquifer — Service Factor 0.586

Drainage ditches are excavated to drain the muskeg and shallow water bearing zones of the mining area in advance of the overburden removal program. The ditches are connected to natural drainage channels. Drainage from the excavated ditches occurs during the non-frozen months and includes drainage from the muskeg dewatering program, drainage from shallow water bearing zones, and runoff from annual precipitation.

Basal Aquifer — Service Factor 1.0

The basal aquifer exists beneath the McMurray oil sands zone. Since the piezometric head of the basal aquifer exists at or near ground surface, it is necessary to depressurize the aquifer to prevent failure of the mine floor. Depressurization is assumed to continue year-round over the life of the mining operation.

Mine Drainage Service Factor 0.465

During the mining operation, mine water is pumped from the mine floor and consists of seepage out of the mine face, drainage from discontinuous water bearing zones encountered during normal mining operations, and runoff from annual precipitation.

.3 Overburden Removal

The average stratigraphic cross-section assumed for this study includes 2 m of muskeg underlain by 23 m of sands, silts, and clays (subsoil). The average thickness of mineable oil sands, underlaying the subsoil has been assumed to be 55 m.

Muskeg Service Factor 0.164

Muskeg, which is stripped from an area equal to the annual mine progression, is directed to the mined-out area for disposal. The operation is undertaken over a two month period during the winter when the ground surface is frozen and involves excavation by large diesel-powered equipment. During the early years of operation, the muskeg is stored in a dyked muskeg storage area until sufficient mined-out space is provided for disposal. Muskeg from the storage area is ultimately utilized in the final mine reclamation program.

Subsoil Service Factor 0.465

Subsoil is excavated by large bucketwheel excavators or draglines. Net subsoil, that material which is not required for dyke construction or for other uses such as road building, is conveyed to the mined-out area for disposal. Stockpiling of net subsoil at grade is undertaken during the early years of operation until sufficient space is provided in the mine.

Muskeg Runoff Service Factor 0.586

Runoff from the muskeg storage area, which includes both interstitial water and runoff from annual precipitation, is routed to natural drainage channels. Sediment load is reduced by providing a retention pond within the dyked area.

Subsoil Runoff Service Factor 0.586

Runoff from the subsoil storage area is routed to natural drainage channels after settling. For options with a tailings pond at the smaller production rate (Options 11 and 13), no subsoil storage area is required since all subsoil excavated during the initial years of operation is utilized as dyke materials.

.4 Fugitive Emissions

Dust Service Factor Variable

Dust emissions are likely to occur periodically from mine-related activities. Since dust emissions are dependent on many uncontrollable and unknown factors, the emission rate and character are not identified. As well, it is expected that remedial measures are employed to minimize dust emissions.

Diesel Emissions Service Factor 0.630

Diesel emissions are a result of the operation of mobile diesel equipment utilized in site preparation, muskeg removal, and other mine-related activities. Diesel emission rates are averaged over the assumed operational periods.

332 EXTRACTION

The four alternative bitumen extraction processes included in the selected options generate waste streams which differ primarily in the nature of the waste solids. Waste solids from hot water extraction and subsequent froth treatment (Options 1, 3, 4, 6, 7, 11, and 13) are discharged from the extraction plant in slurry form (about 49% solids by weight) and are directed to the large tailings pond. Vacuum filtration of whole tailings from hot water extraction and froth treatment in Options 2, 5, and 12 separates the tailings solids and liquids, and enables a portion of the water requirements of hot water extraction to be met by return of the filtrate. The dry tailings (filter cake) are conveyed back to the mine for disposal.

Solvent extraction (Options 8, 9, and 14) and direct coking (Options 10 and 15) generate dry tailings streams and, as well, wastewater which requires treatment prior to reuse.

All of the extraction processes are preceded by a similar raw oil sands feed system which consists of a conveyor feed from the mine or oil sands stockpile area, feed hoppers and screens. Oversize material is removed and is conveyed back to the mine for disposal.

.1 Feed System

Rejects Service Factor 0.8*

Rejects are oversized materials consisting mainly of clay lumps and rocks which are removed by screening after conditioning of the raw oil sands by the addition of steam, hot water and caustic in the hot water extraction options. Rejects are removed by screening in the feed mixer in the solvent extraction options and, in the direct coking options, run-of-the-mine oil sands are screened to remove rejects. Approximately 0.5% of the bitumen input to extraction is removed with the rejects.

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* 0.84 for direct coking

.2 Hot Water Extraction

Steam Vents Service Factor 0.8

Steam is vented from the oil sands conditioning vessel after the addition of hot water, steam and caustic.

Wet Tailings Service Factor 0.8

Within the primary separation cell, the conditioned oil sands (pulp) are separated into a sand layer at the bottom, a bitumen froth layer at the top of the cell, and an intermediate layer (middlings) containing fines and significant quantities of bitumen. The middlings are routed to air flotation cells for scavenging of bitumen and settling of solids. The solids removed from the scavenger units and the sand slurry from the primary separation cell are combined to become hot water extraction tailings. The tailings have a water content of about 50% by weight and contain approximately 7.5% of the bitumen feed to the plant.

.3 Froth Treatment

Wet Tailings Service Factor 0.8

Bitumen-rich froth from primary separation and settled froth from middlings scavenging are conditioned by the addition of naphtha diluent and treated by dilution centrifuging. Solids are removed as tailings (77% water by weight) which are pumped to the tailings pond. The froth treatment tailings contain less than 2% of the bitumen feed to froth treatment and also contain naphtha at about 1.8% by weight.

Vents Service Factor 0.8

Vents from the froth centrifuges and internal tanks, drums and sumps are identified as a single atmospheric emission. A small quantity of naphtha is released via the vents.

.4 Hot Water Extraction/Tailings Filtration

Dry Tailings Service Factor 0.8

Hot water extraction tailings and wet tailings from froth treatment are combined as whole tailings, conditioned with the addition of a flocculant (lime) and filtered by vacuum. The resultant filter cake contains approximately 85% solids, 1% bitumen and 0.15% naphtha.

Filtrate Service Factor 0.8

Filtrate from the vacuum filtration of whole tailings is recycled back to hot water extraction as part of the make-up water requirements. The filtrate contains 4% total solids by weight and less than 3% fine solids by weight (less than 44 microns).

.5 Solvent Extraction

Dry Tailings Service Factor 0.8

Solvent washed fines and sands from the solvent extraction process are drained and steam stripped in a rotary kiln. The resultant dry tailings contain less than 0.1% solvent by weight and approximately 4% of the bitumen input to the extraction plant. For calculation of the density and composition of the dry tailings, it is assumed that the solvent is naphtha.

Vent Gas Service Factor 0.8

Inert gas and air is vented from the solvent extraction process after scrubbing to remove solvent vapours. The vent gas contains approximately 2.5% water by weight and a trace of solvent.

Wastewater Service Factor 0.8

Wastewater from solvent extraction contains trace quantities of organics (bitumen and solvent) and is directed to treatment.

.6 Direct Coking

Spent Sand Service Factor 0.84

Spent sand includes solids removed from the oil sands in the direct coking process, particulates removed from the direct coking product gas and flue gas, gypsum from the lime desulphurization process, unreacted lime, and coke. It is assumed that the moisture content of the spent sand is 5%, after cooling and moistening.

Wastewater Service Factor 0.84

Wastewater from the direct coking process consists of sour water removed from intermediate products after condensation and contains high concentrations of ammonia, phenols and fatty acids. Prior to discharge from the direct coking process, the sour water is steam stripped with pH correction for removal of the steam extractable phenols, and reduction of the ammonia content.

Flue Gas Service Factor 0.84

Products of combustion within the direct coking process are routed through cyclones and electrostatic precipitators to a single stack. Lime added to the direct coking process at a molar ratio of 1:3 (sulphur to calcium) generates $CaSO_4$ with a resultant SO_2 emission rate of 175 ppm (by volume).

Blowdown Service Factor 0.84

Blowdown from the steam generation facilities of the direct coking process is assumed to be 1% of the steam system capacity.

.7 Calcinating Plant

Flue Gas Service Factor 0.84

Lime requirements of the direct coking process are met by calcinating limestone, utilizing natural gas as fuel.

333 UPGRADING

Diluted bitumen from extraction is routed through diluent or solvent recovery process to primary upgrading where the bitumen is upgraded to intermediate product streams using such primary upgrading processes as Fluid Coking, Flexicoking, H-Oil, CANMET or Eureka. Naphtha, gas oil and distillate are subject to further treatment in separate hydrotreaters (secondary upgrading) and diluent or solvent make-up requirements of extraction are produced. The products of secondary upgrading are then blended as synthetic crude. Product sour gases are recovered from primary and secondary upgrading and stripped of H_2S in the amine plant. Resultant sweet process gas is utilized in upgrading and utilities.

Processes which are also included in the upgrading area of the plant are the sulphur plant, sour water stripper and hydrogen plant. For those options where residues from primary upgrading are used to produce a medium joule fuel gas (Options 2 and 7) or used to produce hydrogen (Options 5 and 12), oxygen generation and gasification processes are provided.

In the direct coking options (Options 10 and 15), intermediate products are routed from the direct coking process to secondary upgrading.

.1 Diluent Recovery

Wastewater Service Factor 0.875

Wastewater from the recovery of naphtha from the diluted bitumen contains trace quantities of H_2S, NH_3 and oil and grease. Recovered naphtha is sent back to the inlet of the froth treatment process in the hot water extraction options.

.2 Solvent Recovery

Wastewater Service Factor 0.875

Recovery of solvent from the bitumen product of solvent extraction generates a wastewater with trace quantities of NH_3 and oil and grease.

.3 Fluid Coking

Net Coke Service Factor 0.875

Coke removed from the fluid coking reactor is utilized, for the most part, as a fuel in utility boilers, as a feedstock for the production of medium joule fuel gas, or as a feedstock for production of hydrogen. In Options 1 and 11, the fuel requirements of the conventional coke boilers are less than the total coke residue production, hence, the net coke is sluiced to the coke storage area.

.4 Flexicoking

Char Service Factor 0.875

Coke residue from the Flexicoking reactor is gasified at elevated temperatures, a process which consumes most of the coke. Char from the gasifier includes purge coke, feed metals and other impurities such as fines introduced to the Flexicoking reactor within the feed bitumen.

Coke Fines Service Factor 0.875

Low joule fuel gas (flexigas) produced in the gasifier contains solids in the form of fine coke particles. Prior to utilization of the flexigas in utility boilers, the coke fines are removed in cyclones and scrubbers.

.5 H-Oil

Net Pitch Service Factor 0.875

Pitch residue from the H-Oil reactor is utilized as a feedstock for hydrogen production or as a fuel supply for pitch boilers. In Option

4, the utility fuel requirements are less than the pitch production, hence, the net pitch is conveyed to the pitch storage area after flaking.

Spent Catalyst — Service Factor 0.875

Aged catalysts from the catalytic hydrogen addition process are periodically withdrawn from the reactors. This solid waste stream contains deposits of carbon, sulphur and metals on the active catalyst. It is assumed that spent catalysts are directed off-site for regeneration.

The alternative to spent catalyst regeneration and reuse is disposal by landfilling techniques in the mined-out area.

.6 Sulphur Plant

Sulphur — Service Factor 0.875

Sour gases from primary upgrading and gasification processes are subject to H_2S removal by amine contact and stripping. Acid gases are routed to a multi-train Claus unit with integrated SCOT tail gas clean-up facilities. Elemental sulphur is transported in molten form to the sulphur block for storage. While sulphur sales from the oil sands complex are expected, it is assumed that the dyked sulphur storage area would be capable of storing sulphur produced from five years of operation.

Emissions — Service Factor 0.875

Tail gases from the multi-train Claus and SCOT units are incinerated to oxidize trace amounts of hydrogen sulphide. The sulphur plant is assumed to have an overall sulphur conversion efficiency of 99.9% with the remaining sulphur emitted to the atmosphere as SO_x.

.7 Sour Water Stripper

Wastewater — Service Factor 0.875

Sour water, containing H_2S, NH_3, CO_2 and phenols, is steam stripped in the multi-stage sour water stripper. The resultant H_2S-rich gas is combined with the acid gas feed to the sulphur plant. Ammonia is liquified and directed to the dry ammonia flue gas desulphurization systems in utilities, where applicable, or directed off-site as a by-product (not quantified). The stripped sour water which is not recycled internally is discharged as wastewater. The wastewater has H_2S and NH_3 concentrations of 5 mg/L and 50 mg/L, respectively.

.8 Gasification

Wastewater Service Factor 0.875

Raw gas quench condensate from the gasification of coke or pitch, and gas scrubber liquor are combined to form a wastewater with a high COD, phenolic and ammonia content. The wastewater is steam stripped for NH_3 reduction before discharge from the gasification unit.

CO_2 Vent Service Factor 0.875

Carbon dioxide is removed from the product gas in Option 7 where pitch is gasified to produce a medium joule fuel gas. Carbon dioxide is vented directly to the atmosphere.

Slag Service Factor 0.875

Slag from the gasification process consists of mineral matter which is present in the feed coke or pitch, unreacted coke or pitch, and solids scrubbed from the product scrubber.

.9 Oxygen Plant

Emissions Service Factor 0.875

The oxygen requirements of coke or pitch gasification to medium joule fuel gas (Options 2 and 7) and of partial oxidation of pitch for hydrogen production (Options 5 and 12) are generated in the oxygen plant. Oxygen is produced by compressing air to high pressures and distilling the oxygen from the nitrogen.

.10 Hydrogen Plant Service Factor 0.875

Hydrogen is required for secondary upgrading in the naphtha, gas oil and distillate hydrotreaters and in the hydrogen addition upgrading processes (H-Oil and CANMET). Hydrogen is produced in a multi-train system by steam reformation of natural gas and process gas. In Options 5 and 12, synthesis gas generated by the partial oxidation of pitch is used to generate additional hydrogen. The synthesis gasis purified in a shift converter and by acid gas stripping to produce hydrogen.

Process Condensate Service Factor 0.875

Condensate from the reformers is saturated with CO_2 and contains trace quantities of hydrogen and hydrocarbons.

Wastewater Service Factor 0.875

Raw gas quench condensate and gas scrubbing liquor are produced in the pitch partial oxidation unit. The wastewater is steam stripped for ammonia reduction prior to discharge. It is assumed that this wastewater stream is of similiar quality to the wastewater from gasification of pitch for medium joule fuel gas production.

Stripped Water — Service Factor 0.875

Sour water from hydrogen purification is stripped to reduce the ammonia content to 50 mg/L.

CO_2 Vent — Service Factor 0.875

Carbon dioxide, which is removed in the production of high purity hydrogen, is vented to the atmosphere.

Slag — Service Factor 0.875

The residue from the partial oxidation of pitch contains mineral matter which is present in the feed pitch and unreacted pitch which combine to form a slag.

Char — Service Factor 0.875

Carbon fines, or char, are removed from the synthesis gas prior to carbon monoxide conversion and purification of the hydrogen product.

.11 Upgrading Fired Heaters

Emissions — Service Factor 0.875

Process heating is provided in part by process gas fired heaters in the upgrading area. Emissions from the heaters are a result of the combustion of sweet process gas at 20% excess air.

.12 Steam Generation

Blowdown — Service Factor 0.875

Within upgrading, a portion of steam requirements is met by waste heat utilization. Condensate blowdown is assumed to be 1% of the steam system capacity.

334 UTILITIES

The utility plant produces steam, power and water as required by mining, extraction, upgrading and offsites. The fuel inputs to the boilers vary with the upgrading residue management scheme established for the selected options and with the residue composition. Emissions have been computed directly from the fuel composition, assuming complete combustion.

For each boiler and superheater, NO_x emissions have been assumed to be equal to the maximum nitrous oxide emission objectives for the respective input fuels. Control of NO_x emissions is achieved by boiler design factors and operational measures.

The need for flue gas desulphurization on boilers fired by high sulphur fuels is determined by examining the total complex SO_2 emissions. SO_2 removal efficiencies for each boiler are established in order to meet the overall plant SO_2 emissions objective of 3.2 tonnes SO_2 per 1000 m^3 of bitumen feed to upgrading.

.1 Boiler Plant

Blowdown	Service Factor 0.875

Condensate from the steam system is blown down to control water quality. Blowdown is assumed to be 1% of the steam system capacity.

.2 CO Boilers

Emissions	Service factor 0.875

Combustion products from fluid coking supplemented with sweet process gas are combusted at 20% excess air in the CO boilers. Flue gases are routed to flue gas treatment for particulate and SO_2 reduction prior to venting to atmosphere.

Fly Ash	Service Factor 0.875

Particulate removal is achieved in electrostatic precipitators with a design removal efficiency of 99%.

Prescrubber Blowdown	Service Factor 0.875

Blowdown from the pre-scrubber of the ammonia desulphurization system is assumed to contain up to 90% of the fly ash within the flue gas and, although not further characterized, is expected to contain other constituents dissolved from the flue gas.

FGD Byproduct	Service Factor 0.875

Liquid byproduct from the FGD facility contains about 19.2% ammonium bisulphite and 7.5% ammonium sulphite. Subject to overall quality and marketability, it is assumed that the FGD byproduct is transported off-site as a feedstock for the manufacture of ammonia fertilizer.

.3 Coke or Pitch Boilers (Conventional)

Emissions — Service Factor 0.875

Flue gases from the combustion of coke and sweet process gas (Options 1 and 11) and from the combustion of pitch and natural gas (Option 4) are treated in electrostatic precipitators and ammonia desulphurization systems prior to venting to atmosphere. Products of combustion have been computed for each input fuel combination at 20% excess air, and have been corrected to reflect the required SO_2 removal rate and maximum NO_x emission rates.

Bottom Ash — Service Factor 0.875

Bottom ash is assumed to be 20% of the input fuel ash. The bottom ash, which contains mineral matter and metals present in the residues from primary upgrading, is sluiced to hydrobins for solid/liquid separation and is subsequently transported to the mine for disposal.

Fly Ash — Service Factor 0.875

Removal of particulates from the boiler flue gases is achieved in electrostatic precipitators. The efficiency of particulate removal is assumed to be 99%.

Ash Sluice Blowdown — Service Factor 0.8

Blowdown from the bottom ash sluice system contains suspended solids and chemicals leached from the ash.

Prescrubber Blowdown — Service Factor 0.8

Blowdown from the prescrubber of the ammonia desulphurization system is assumed to contain 90% of the fly ash within the flue gas and, although not further characterized, will contain other constituents dissolved from the flue gas.

FGD Byproduct — Service Factor 0.8

Liquid byproduct from the flue gas desulphurization system contains about 19.2% ammonium bisulphite and 7.5% ammonium sulphite. Subject to overall quality and marketability, it is assumed that the FGD byproduct is transported off-site as a feedstock for the manufacture of ammonia fertilizer.

.4 Coke or Pitch Boilers (FBC)

Emissions Service Factor 0.8

Limestone is added to the fluidized bed of the coke FBC boilers (Option 8) and the pitch FBC boilers (Options 6 and 13) to remove sulphur. A sulphur to calcium molar feed ratio of 1:4 is assumed with a sulphur removal efficiency of 90%. Products of combustion have been computed at 20% excess air, and have been corrected to reflect the SO_2 reduction and the maximum NO_x emissions rate.

Spent Bed Solids Service Factor 0.8

Spent bed solids contain the gypsum product of desulphurization ($CaSO_4$), unreacted lime, and 20% of the ash content of the coke or pitch fuel.

Fly Ash Service Factor 0.8

Particulate emissions from the fluidized bed boilers are reduced by electrostatic precipitators which remove 99% of the fly ash in the flue gas.

.5 Waste Heat Boilers

Emissions Service Factor 0.8

Waste heat from the gas turbines supplemented with natural gas is utilized to raise steam in waste heat boilers. Emissions are typical products of the combustion of natural gas.

.6 Gas Fired Boilers

Emissions Service Factor 0.8

Steam is raised in gas fired boilers utilizing natural gas, sweet process gas, medium joule fuel gas from residue gasification, flexigas, or a combination of these fuels. Emissions have been computed at 20% excess air for each gas fired boiler from the input fuel composition and have been corrected to reflect the maximum NO_x emissions rate.

.7 Superheaters

Emissions Service Factor 0.8

Superheaters are fired by natural gas, sweet process gas, medium joule fuel gas or a combination of these fuels. Emissions have been computed at 10% excess air for the superheaters and have been corrected to reflect the maximum NO_x emissions rate.

.8 Cooling Towers

Blowdown Service Factor 0.8

Four cycles of concentration of the non-volatile constituents of the cooling tower make-up water are assumed for cooling tower blowdown characterization. Make-up is assumed to be settled Athabasca River water. Sulphuric acid is added for pH control of the cooling water and it is assumed that non-chromate inhibitors are used in the system.

.9 Water Treatment Plant

Boiler feedwater is produced in the utilities water treatment plant. Treatment of settled Athabasca River water includes warm lime softening, filtration and demineralization.

Softener Solids Service Factor 0.8

Sludge from warm lime softening is removed from the reactor at 5% solids and is centrifuged to 60% solids. The centrate is recyled to the inlet of the softener.

Regenerate Waste Service Factor 0.8

Wastewater from the regeneration of ion exchangers is a combination of dilute acid solution from the cation exchangers and dilute caustic solution from the anion exchangers. Neutralization of the regenerant wastewater by lime addition is undertaken prior to discharge.

335 OFFSITES

.1 Flare

Emissions Service Factor 0.875

Emissions from the flare system are a result of combustion of the purge stream of process gas. During normal operations, flaring of vapours from vessels within gas recovery and secondary upgrading is undertaken, thus increasing the contaminant emission from the flare system.

.2 Tankage

Tank Bottoms Service Factor 0.082

Diluted bitumen and bitumen storage tanks are provided for surge storage and to provide a 30 day uninterrupted feed bitumen supply to upgrading during any planned or unplanned extraction plant shutdowns. Tank bottoms are steam stripped from the storage tanks annually over a 30 day period.

.3 Condensate Leakage

Condensate Service Factor 0.875

Steam or hot water leakage from heat exchangers generates an oil-contaminated condensate within product streams. Dirty condensate is subsequently removed from the system in knockout drums. It is assumed that the contaminated condensate has an average oil and grease content of 1000 mg/L.

.4 Building Drains

Washdown Service Factor 0.875

Wastewater from clean-up operations in upgrading and utilities generates wastewater of varying quality. It is assumed that the wastewater will contain, on average, 1000 mg/L oil and grease, and 1000 mg/L total suspended solids. Water requirements for clean-up operations are assumed to be 15.2 L/s for the larger complexes and 7.6 L/s for the smaller complexes.

.5 Runoff

Inplant Runoff Service Factor 0.586

Runoff from precipitation in the processing areas of the complex is assumed, for quantification purposes, to be collected within the process waste sewer system equally over the non-frozen months (214 days). A runoff coefficient of 0.8 is assumed. In all options, a storm pond is provided to store runoff in excess of the average flow during storm conditions and during the spring runoff period.

Clean Runoff Service Factor 0.586

Runoff from non-processing areas of the plant is collected in drainage ditches and is discharged to natural drainage channels.

.6 Potable Water Treatment Plant

Alum Sludge Service Factor 1.0

Water from the raw water pond supplies the potable water treatment plant. Treatment involves coagulation/flocculation, settling, filtration and disinfection. Waste alum sludge is discharged from the treatment plant at 3% solids. Sludge production is 60 m^3/d for the options producing syncrude at the higher rate (work force of 2500 persons) and 30 m^3/d for the options producing syncrude at the lower rate (work force of 1250 persons).

.7 Sewage Treatment Plant

Effluent — Service Factor 1.0

Sanitary sewage from the complex is generated at the rate of 0.45 m^3/worker/day and is treated in the secondary sewage treatment plant. The plant is a rotating biological contactor unit which includes two primary clarifiers, four bio-disc units, a secondary clarifier and two aerobic digestors. Effluent from the plant contains 25 mg/L BOD, 25 mg/L total suspended solids and 25 mg/L oil and grease.

Digested Sludge — Service Factor 1.0

Sludge from aerobic digestion has a solids content of 5% by weight.

.8 Coke Storage Area

Coke Sluice Blowdown — Service Factor 0.875

Net coke from Options 1 and 11 is stored in the dyked coke storage area. Blowdown from the coke sluicing system includes runoff from precipitation input to the storage area.

.9 Pitch Storage Area

Runoff — Service Factor 0.586

The character of runoff from the pitch storage area required in Option 4 is estimated from the pitch composition.

.10 Sulphur Block

Runoff — Service Factor 0.586

Runoff from the sulphur block is expected to contain up to 200 mg/L of suspended solids, primarily elemental sulphur particles, and trace amounts of thiosulphides. Sulphur is essentially non-reactive over the normal conditions to which it is exposed, however, during the spring runoff period, runoff may be more acidic.

.11 Solid Waste

Emissions — Service Factor 1.0

Solid waste is generated within the complex at the rate of 2 kg/worker/day. The combustible fraction (75%) is incinerated under controlled air conditions generating emissions to the atmosphere.

Non-combustibles Service Factor 1.0

Ash from the incineration of the combustible solid waste fraction and non-combustible solid waste (mostly ferrous metals) is transported to the mined-out area for disposal.

3.4 WASTE STREAM CHARACTERIZATION

341 DATA PRESENTATION

Waste stream characterization data for each unit process are stored in a computerized data storage and retrieval system. The system for data storage, manipulation and presentation used for this study is made up of two parts. The data entry, modification and report modules make up the data base portion which is run on a Digital mainframe computer. The nature of the data base design allows quick access to and retrieval of interrelated data attributes, as well as sophisticated reporting functions. Data are entered via a video display terminal, and lists or reports may be printed on a hard copy terminal or via a high speed printer.

Once the data is finalized, it is ready for formatting on the pre-drawn matrices and flow diagrams. Data is selected and electronically transferred to a Digital mini-computer dedicated to computer aided drafting and design. Here a program is run which takes the transferred data and graphically places them in specified locations on the pre-drawn matrices. Matrices can contain up to 3700 data entries so the computer generated matrices represent a considerable time saving over conventional drafting.

Stream day waste flows are used for flow rate identification and are representative of average operating day wastes generation. For those wastes which accumulate over a year, e.g. sulphur, the annual accumulation may be computed by applying the service factor for the waste stream.

Waste stream characterization data are presented for each of selected options in matrix format. Space limitations have necessitated two matrix sheets for the complete characterization of gaseous, liquid and solid waste emissions for each option.

Summaries of all waste streams from the unit processes within the selected options are displayed on pollutant flow diagrams. The diagrams also show the conceptual waste collection and distribution network, total stream day and total annual flows in each collection system, and the waste management scheme (described in detail in Part 4).

Figure 3-1 shows the data presentation format and identifies the relationships between the matrices and pollutant flow diagrams. Within the matrices, each waste stream is identified by the area of the complex from which the waste is generated, the unit process, waste stream description and identification number. Waste stream flow rate, emission temperature, density and pH (when applicable or known) are displayed in the units as indicated. Both concentration and daily loading for other characterization parameters are provided. Concentrations are reported in mg/L for liquid waste streams, mg/kg for solid waste streams, and mg/m^3 for gaseous waste streams. All loading data are reported in kg/d. Exponential format is used to identify large numbers (greater than 9999) in order to conserve space within the matrix. Waste streams are identified in the pollutant flow diagrams by the waste stream identification number established in the waste management matrix.

In the example shown in Figure 3-1, wet tailings from hot water extraction, consisting of approximately 617 000 mg/L solids, 609 000 mg/L water and 6 776 mg/L bitumen, are directed to the tailings pond via the tailings line. Approximately 2.2 million kg/sd of bitumen are discharged from hot water extraction within the wet tailings. The pollutant flow diagram also shows the total flow per stream day to the tailings pond, identifies the annual input to the tailings pond and shows the stream day quantity of water reclaimed from the pond.

342 WASTE MANAGEMENT MATRICES AND POLLUTANT FLOW DIAGRAMS

Matrices 3-1 to 3-30 and Figures 3-2 to 3-16 provide the complete waste characterization data for all selected options. For each option, the order of the data presentation sheets is as follows:

1. Waste Management Matrix - Liquid Waste Streams;
2. Waste Management Matrix - Solid and Gaseous Waste Streams; and
3. Pollutant Flow Diagram.

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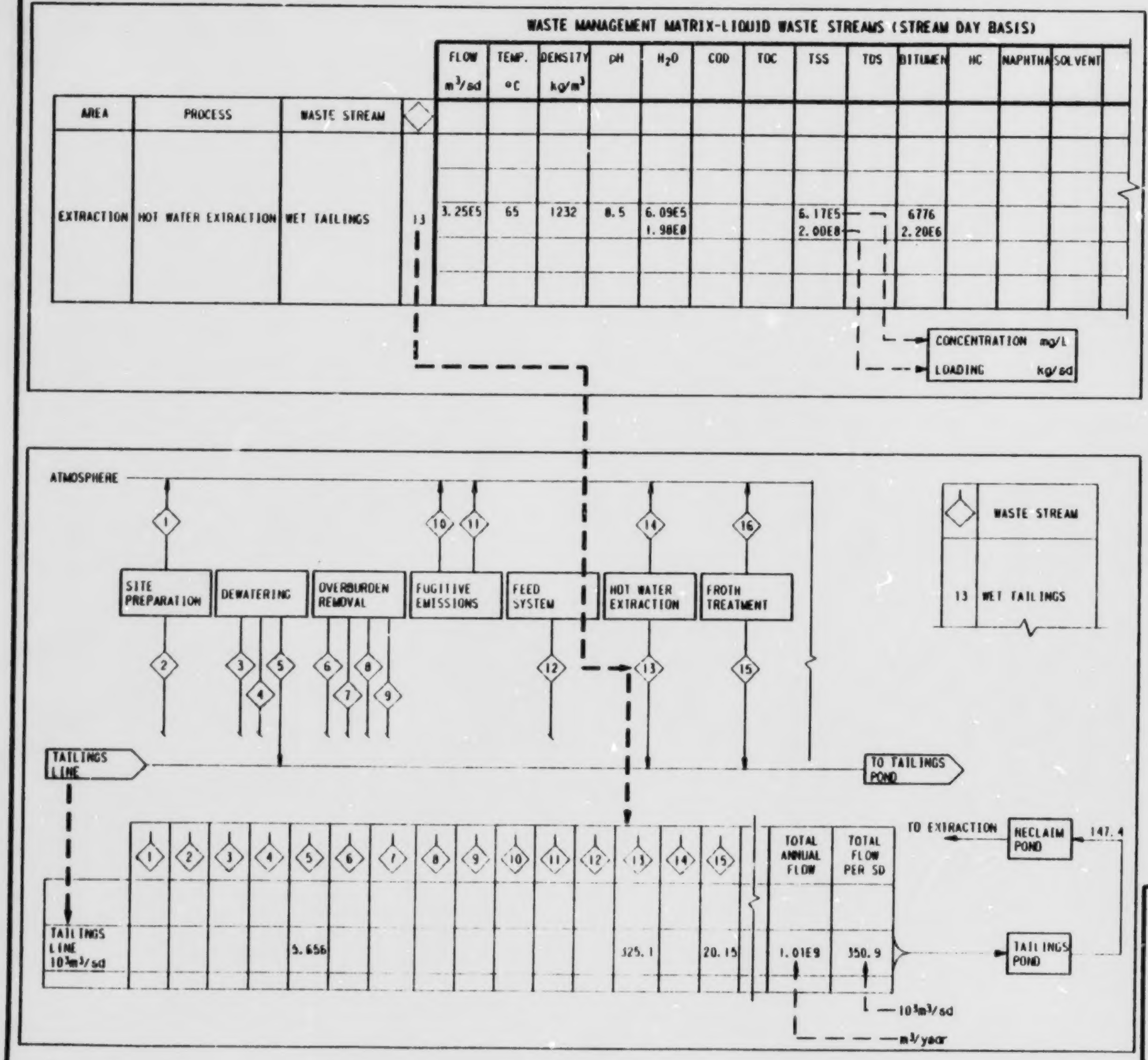
WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)
AREA
PROCESS
WASTE STREAM
FLOW m³/sd
TEMP. °C
DENSITY kg/m³
pH
H₂O
COD
TOC
TSS
TDS
BITUMEN
HC
NAPHTHA
SOLVENT
EXTRACTION
HOT WATER EXTRACTION
WET TAILINGS
13
3.25E5
65
1232
8.5
6.09E5
1.98E8
6.17E5
2.00E8
6776
2.20E6
CONCENTRATION mg/L
LOADING kg/sd
MATRIX
ATMOSPHERE
1
10
11
14
16
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
HOT WATER EXTRACTION
FROTH TREATMENT
2
3
4
5
6
7
8
9
12
13
15
TAILINGS LINE
TO TAILINGS POND
WASTE STREAM
13 WET TAILINGS
POLLUTANT FLOW DIAGRAM
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
TOTAL ANNUAL FLOW
TOTAL FLOW PER SD
TAILINGS LINE 10³m³/sd
5.656
325.1
20.15
1.01E9
350.9
10³m³/sd
m³/year
TO EXTRACTION
RECLAIM POND
147.4
TAILINGS POND

FIGURE 3-1

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

EXAMPLE - DATA PRESENTATION

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AREA	PROCESS	WASTE STREAM	◇	FLOW m^3/sd	TEMP. °C	DENSITY kg/m^3	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3	TKN
MINING	DEWATERING	SHALLOW AQUIFER	3	1710		1000	7.6						295 504					
		BASAL AQUIFER	4	6700		1005	7.4						1440 9640					
		MINE WATER	5	5656		1000	8.3			12 67.9							.28 1.58	
	OVERBURDEN	MUSKEG RUNOFF	8	1661		1000	7.3		34 56.5	8 13.3		64.6 107	78.7 131					.35 .581
		SUBSOIL RUNOFF	9	691		1000	7.6				38 20.7							
EXTRACTION	HOT WATER EXTRACTION	WET TAILINGS	13	3.25E5	65	1232	8.5	6.09E5 1.98E8										
	FROTH TREATMENT	WET TAILINGS	15	2.02E4	75	1079	8	8.31E5 1.67E7										
UPGRADING	DILUENT RECOVERY	WASTEWATER	17	2419	88	1000										TRACE	TRACE	
	SOUR WATER STRIPPER	SWS WASTEWATER	21	4200	140	1000	8.1		295 1239		204 857					5 21	50 210	
	HYDROGEN PLANT	CONDENSATE	22	2462		1000								TRACE	19 46.8			
	UPGRADING STEAM	BLOWDOWN	24	233	174	1000	9.5											
UTILITIES	BOILER PLANT	BLOWDOWN	25	497	174	1000	9.5					400 199						
	CO BOILERS	PRESCRUBBER BD	28	1550		1000												
		FGD BYPRODUCT [1]	29	572	45	1020		7.71E5 4.41E6										
	COKE BOILERS	ASH SLUICE BD	33	366	71	1000	6.4			170 62.2								11.5 4.2
		PRESCRUBBER BD	34	1317		1000												
		FGD BYPRODUCT [1]	35	2217	45	1052		7.71E5 1.71E6										
	COOLING TOWER	BLOWDOWN	37	4870	24	1000	7.5				50 244	50 244					10 48.7	
	WATER T'MENT PLANT	REGENERANT WASTE	39	2700		1000	7						145 392					
OFFSITES	TANKAGE	TANK BOTTOMS	41	41		1100		4.33E5 1.76E4										
	CONDENSATE LEAKAGE	CONDENSATE	42	259		1000						400 104						
	BUILDING DRAINS	WASHDOWN	43	1308		1000	8.1						158 207				.12 .157	1.2 1.57
	SURFACE RUNOFF	INPLANT RUNOFF	44	4489		1000	7.6		511 2292	10 44.9	74.1 333	90 404						7.07 31.7
		CLEAN RUNOFF	45	653		1000	7.6		511 333		74.1 48.4							7.07 4.62
	POTABLE WATER T'MENT	ALUM SLUDGE	46	60		1000		9.70E5 5.82E4										
	SEWAGE TREATMENT	EFFLUENT	47	1140		1000					25 28.5							
		DIGESTED SLUDGE	48	9		1022		9.49E5 8654										
	COKE STORAGE	COKE SLUICE BD	49	366		1000	7.8			170 62.2								11.5 4.2
	SULPHUR STORAGE	BLOCK RUNOFF	50	34		1000	6											

[1] ALSO CONTAINS 19.2%wt NH_4HSO_3 AND 7.5%wt $(NH_4)_2SO_3$

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WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

OD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3	TKN	NO_3	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	SOLVENT	OIL & GREASE	PHENOL	DEA	SO_4	SULPHIDES	S_2O_3	PO_4	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
				295 504						7 12			467 799									11 18.8				34 58.1				68 116	24 41		72 123	3 5.13												6 10.3			
				1440 9640									3778 2.53E4									55 369	23.5 157			1060 7102				55 369	30 201		1137 7618					.9 6.03			.5 3.35								
	12 67.9							.28 1.58				6.5 36.8	400 2262						3 17								.23 1.3			99.7 564	24.8 140	.31 1.75	66 373	2.87 16.2			.19 1.07		.004 .023	.007 .04	.05 4.81		.021 .119	.011 .062		8.25 46.7	.39 2.21		.046 .26
4 .5	8 13.3		64.6 107	78.7 131					.35 .581			365 606	10 16.6									.1 .166				1.7 2.82	.06 .1			16.5 27.4	4.5 7.47		4.9 8.14	.5 .831												2.2 3.65			
		38 28.7										6123 4232	150 104													10 6.91				15 10.4	5 3.46		15 10.4																
												6.17E5 2.00E8			6776 2.20E6																																		
												2.02E5 4.06E6			2.70E4 5.43E5		1.94E4 3.91E5																																
							TRACE	TRACE											TRACE																														
5 39		204 857					5 21	50 210				10 42								12 50.4		33 139		150 630		117 491		.1 .42	.36 1.51	9 37.8									.07 .294		8.8 37					2.6 10.9			
					TRACE	19 46.8										TRACE																																	
													120 28													9 2.1							14 3.26													6 1.4			
			400 199									150 74.5	2500 1242																	500 248																35 17.4			
												321 497																																					
	170 62.2								11.5 4.2			2060 753	775 283						10 3.66	.062 .023			.1 .037		2.18 .797					17.2 6.29	7.63 2.79	.44 .161	255 93.2	13.8 5.05	21.9 8.01	.08 .029	.75 .274	.25 .091	.049 .018	.2 .073	19.7 7.2	TRACE	.12 .044	.28 .102	.02 .007	66.2 24.2	.34 .124	.87 .318	.12 .044
												1215 1600																																					
		50 244	50 244					10 48.7				160 779	725 3531						10 48.7			290 1412			TRACE	30 146				170 828	40 195	.24 1.17	95 463	8 39	1.84 8.96		.64 3.12		.032 .156	TRACE	4.9 23.9	.2 .974	.044 .214			36 175			
				145 392									6490 1.75E4									3741 1.01E4				481 1299				460 1242	138 373		1398 3775	25 67.5												103 278			
											9.13E4 3717								5.75E5 2.34E4																														
			400 104									1000 259	2500 648						1000 259											150 38.9																35 9.07			
				158 207				.12 .157	1.2 1.57	.046 .06		1000 1308	200 262						1000 1308	3 3.92	270 353	15.1 19.8	32 41.9		1.05 1.37	7.7 10.1	.11 .144			41.8 54.7	9 11.8		23.5 30.7	1.7 2.22			.16 .209									12 15.7			
2	10 44.9	74.1 333	90 404						7.07 31.7	3.17 14.2		1170 5252	350 1571						200 898	.025 .112					1.6 7.18	52 233				15 67.3	5 22.4		15 67.3												52 233				
		74.1 48.4							7.07 4.62	3.17 2.07		660 431	200 131													26 17				15 9.8	5 3.27		15 9.8																
												3.00E4 1800																																					
		25 28.5										25 28.5							25 28.5																														
												5.11E4 466																																					
	170 62.2								11.5 4.2			1680 614	835 305						10 3.66	.062 .023			.1 .037		2.18 .797					17.2 6.29	7.63 2.79	.44 .161	255 93.2	13.8 5.05	21.9 8.01	.08 .029	.75 .274	.25 .091	.049 .018	.2 .073	19.7 7.2	TRACE	.12 .044	.28 .102	.02 .007	66.2 24.2	.34 .124	.87 .318	.12 .044
												200 6.74												TRACE																									

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L	500
LOADING kg/sd	1440

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-1

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS FROM A MINING OIL SANDS COMPLEX
OPTION I HOT WATER EXTRACTION/FLUID COKING/ CO & COKE BOILERS
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WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY	SPENT CATALYST	TOTAL ORG.	TOTAL INORG.	LIME	$CaCO_3$	$CaSO_4$	METALS
MINING	SITE PREPARATION	ASH	2	812		400		5000 4.06				5.90E4 47.9												
	OVERBURDEN	MUSKEG	6	3.05E7		840	7.6												9.76E5 2.98E7	2.40E4 7.32E5				
		SUBSOIL	7	1.72E8		1600	7.5								6.30E5 1.08E8	2.07E5 3.57E7	1.62E5 2.79E7							
EXTRACTION	FEED SYSTEM	REJECTS	12	9.05E6	82	1484	8.5	1.19E5 1.17E6	1.50E4 1.48E5						8.37E5 8.24E6	8661 8.53E4	2.08E4 2.05E5							
UPGRADING	FLUID COKING	NET COKE	18	1.80E5		1200		1000 180				7.10E4 1.28E4												
	SULPHUR PLANT	SULPHUR	20	8.30E5		2046		100 83.8				2 1.67												
UTILITIES	CO BOILERS	FLY ASH	27	5.42E4	430	2100	8.5																	
	COKE BOILERS	BOTTOM ASH	31	4.30E4	80	2400	8																	
		FLY ASH	32	1.76E5	430	2100	8.5																	
	WATER T'MENT PLANT	SOFTENER SOLIDS	38	3.58E4		2040		4.00E5 1.43E4														6.00E5 2.15E4		
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	52	1663		4700						5.49E5 913												4.51E5 750

WASTE STREAM	◇	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo
ASH	2		1.10E5 89.3					8.50E5 690	2.53E5 205				6.40E4 52		2.40E4 19.5		4.10E4 33.3	1.50E4 12.2	
MUSKEG	6																		
SUBSOIL	7																		
REJECTS	12																		
NET COKE	18	.4 .072	6930 1247			30 5.4		7.70E5 1.39E5	602 108	10 1.8	51 9.18	11 1.98	2570 463	1.45E4 2610		4.35E4 7830	272 49	49 8.82	121 21.8
SULPHUR	20							15 12.6											
FLY ASH	27		3.31E5 1.79E4						3.31E4 1791				9.92E4 5374						
BOTTOM ASH	31		2.71E5 1.16E4						4.12E4 1772				8.60E4 3699		2.14E4 920		1.43E4 615	2600 112	
FLY ASH	32		3.31E5 5.81E4						3.31E4 5806				9.92E4 1.74E4						
SOFTENER SOLIDS	38																		
NONCOMBUSTIBLES	52																		

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m³	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
MINING	SITE PREPARATION	EMISSIONS	1	2.63E4	400	101	1.25E6	1.12E5 2942	3.32E5 8724						7.87E5 2.07E4			1.32E4 348		550 14.5				
	FUGITIVE EMISSION	DUST *	10																					
		DIESEL EMISSIONS	11	1.33E4	540	101	1.11E6		560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	330 4.4	1.50E4 200		1.88E4 250	5.46E4 728		5110 68.1	2780 37.1
EXTRACTION	HOT WATER EXTRACTION	STEAM VENTS	14	1.89E6	200	101	7.62E5	7.62E5 1.44E6																
	FROTH TREATMENT	VENTS	16	1.14E4		101	1.47E6	7.72E4 882	798 9.12		2.58E5 2944				7.62E5 8709			1.76E4 201				3.50E5 4003		
UPGRADING	SULPHUR PLANT	EMISSIONS	19	2.59E6	538	105	1.20E6	3.98E4 1.03E5	9.30E4 2.41E5			634 1642	6.77 17.5		1.06E6 2.75E6	211 547								
	UPGRADING HEATERS	FLUE GAS	23	2.17E7	400	110	1.24E6	9.13E4 1.98E6	2.75E5 5.97E6		4.19E4 9.10E5	160 3472	2 43.4		8.19E5 1.78E7	270 5859		1.52E4 3.30E5						
UTILITIES	CO BOILERS	FLUE GAS	26	1.75E7	43	101	1.24E6	6.92E4 1.21E6	2.60E5 4.56E6		1.74E4 3.05E5	853 1.49E4	11 193		8.90E5 1.56E7	221 3872	TRACE	5854 1.03E5		3.1 54.3				
	COKE BOILERS	FLUE GAS	30	5.33E7	43	101	1.24E6	6.92E4 3.69E6	2.38E5 1.27E7		4.71E4 2.51E6	1020 5.44E4	13 693		8.70E5 4.64E7	539 2.87E4	TRACE	1.77E4 9.43E5		3.3 176				
	PG SUPERHEATERS	FLUE GAS	36	2.66E6	68	101	1.18E6	1.32E5 3.52E5	1.71E5 4.54E5		2.38E4 6.34E4	138 368	1.75 4.66		8.38E5 2.23E6	291 774		1.54E4 4.10E4	4.38 11.7					
OFFSITES	FLARE	EMISSIONS	40	1.04E5	1000	101	1.19E6	1.32E5 1.37E4	1.95E5 2.02E4			600 62.3	8 .831		8.44E5 8.76E4			1.42E4 1471						
	SOLID WASTE	INCINERATOR EMIS	51	1.78E4	650	103	1.23E6	1.22E5 2164	3.06E5 5444			122 2.16	1.5 .027		7.99E5 1.42E4	1105 19.6				123 2.19				

* NOT CHARACTERIZED

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS NOTED OTHERWISE

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
		6.40E4 52		2.40E4 19.5		4.10E4 33.3	1.50E4 12.2			8.00E4 65				2.10E4 17.1			3.20E5 260	8000 6.5		
51 9.18	11 1.98	2570 463	1.45E4 2610		4.35E4 7830	272 49	49 8.82	121 21.8	6200 1116	370 66.6	660 119		20 3.6	7.90E4 1.42E4				1160 209	1590 286	13 2.34
														1.00E6 8.37E5						
		9.92E4 5374								8264 448							5.29E5 2.87E4			
		8.60E4 3699		2.14E4 920		1.43E4 615	2600 112			9900 426	1.53E4 658	1100 47.3					4.30E5 1.85E4	3.70E4 1591	6.25E4 2688	
		9.92E4 1.74E4								8264 1451							5.29E5 9.29E4			

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

DATA PRESENTATION: GASES

PARAMETER	CO_2
CONCENTRATION mg/m^3	4000
LOADING kg/sd	1.42E6

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

MATRIX 3-2

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

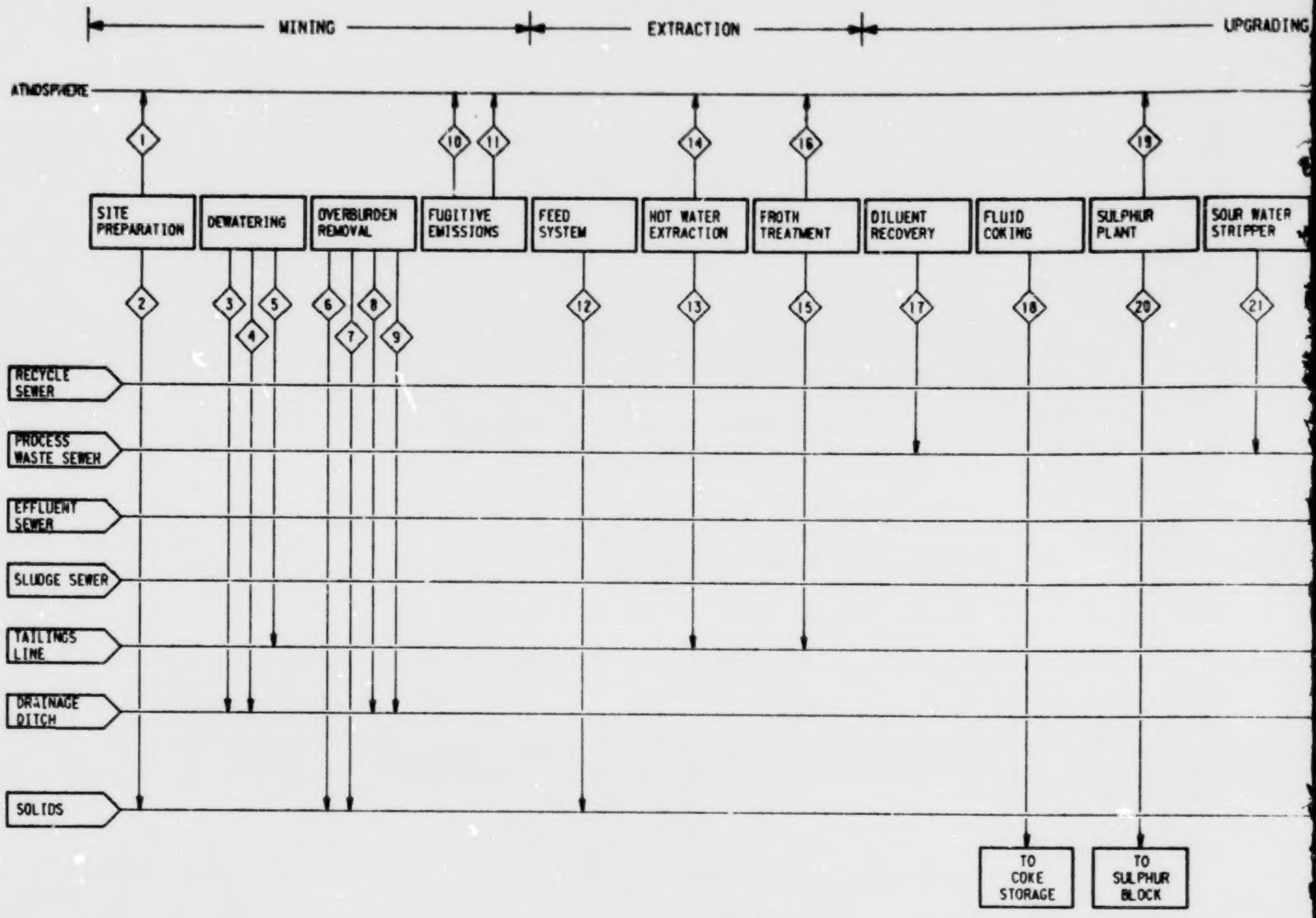
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 1 HOT WATER EXTRACTION/FLUID COKING
CO & COKE BOILERS

MONENCO CONSULTANTS LIMITED

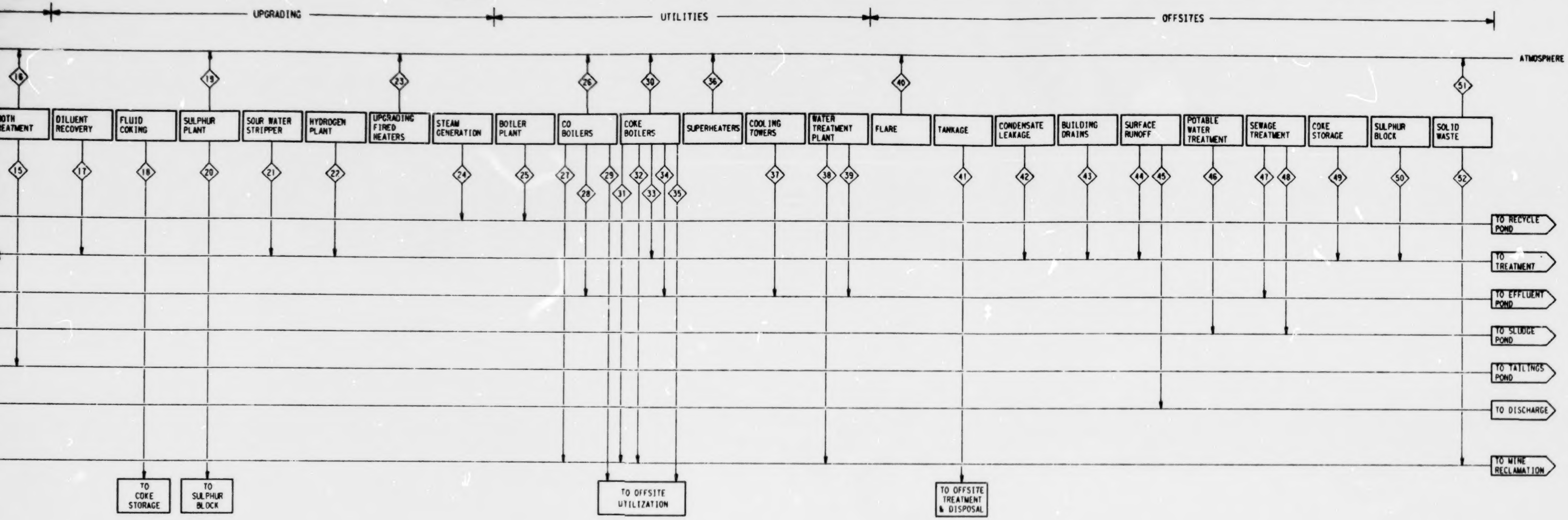
M00235.CNT F24

3


MINING
EXTRACTION
UPGRADING
ATMOSPHERE
1
10
11
14
16
19
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
HOT WATER EXTRACTION
FROTH TREATMENT
DILUENT RECOVERY
FLUID COKING
SULPHUR PLANT
SOUR WATER STRIPPER
2
3
4
5
6
7
8
9
12
13
15
17
18
20
21
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
TAILINGS LINE
DRAINAGE DITCH
SOLIDS
TO COKE STORAGE
TO SULPHUR BLOCK

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
ATMOSPHERIC EMISSIONS $10^6 m^3/sd$	0.026									*	0.013			1.893		0.011			2.590				21.70			17.52
RECYCLE SEWER $10^3 m^3/sd$																								0.233	0.497	
PROCESS WASTE SEWER $10^3 m^3/sd$																	2.419				4.200	2.462				
EFFLUENT SEWER $10^3 m^3/sd$																										
SLUDGE SEWER $10^3 m^3/sd$																										
TAILINGS LINE $10^3 m^3/sd$					5.656								325.1		20.15											
DRAINAGE DITCH $10^3 m^3/sd$			1.710	6.700				1.661	0.691																	
SOLIDS t/sd		0.812				30500	172000					9845														
OTHER SOLIDS t/sd																		180		837.5						
OTHER LIQUIDS $10^3 m^3/sd$																										

* NOT QUANTIFIED


UPGRADING
UTILITIES
OFFSITES
ATMOSPHERE
OTH
EATMENT
DILUENT RECOVERY
FLUID COKING
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
BOILER PLANT
CO BOILERS
COKE BOILERS
SUPERHEATERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
COKE STORAGE
SULPHUR BLOCK
SOLID WASTE
16
19
23
26
30
36
40
51
15
17
18
20
21
22
24
25
27
28
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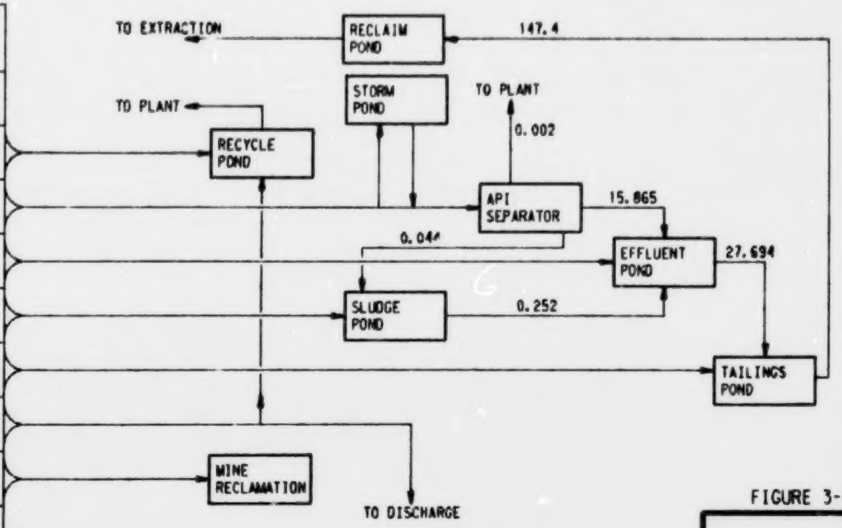
48
49
50
52
TO RECYCLE POND
TO TREATMENT
TO EFFLUENT POND
TO SLUDGE POND
TO TAILINGS POND
TO DISCHARGE
TO MINE RECLAMATION
TO COKE STORAGE
TO SULPHUR BLOCK
TO OFFSITE UTILIZATION
TO OFFSITE TREATMENT & DISPOSAL

5	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	TOTAL ANNUAL FLOW +	TOTAL FLOW PER SD
	0.011			2.590				21.70			17.52				53.32						2.661				0.104											0.018		3.03E10	99.86
									0.233	0.497																												2.20E5	0.730
		2.419				4.200	2.462											0.366									0.259	1.308	4.489					0.366	0.034			4.54E6	15.903
													1.550						1.317			4.870		2.700								1.140						3.50E6	11.577
																															0.060		0.009					2.52E4	0.069
15																																						1.02E8	350.9
																														0.653								3.45E6	11.415
												54.2				43	175.6						35.8														1.663	3.40E7	212656
			180		837.5																																	3.25E5	10175
														0.572						2.217						0.041												8.31E5	2.830

+ UNITS FOR TOTAL ANNUAL FLOW: ATMOSPHERIC EMISSIONS m³/yr
LIQUID STREAMS m³/yr
SOLIDS t/yr


TO EXTRACTION
RECLAIM POND
147.4
STORM POND
TO PLANT
TO PLANT
0.002
RECYCLE POND
API SEPARATOR
15.865
0.044
EFFLUENT POND
27.694
SLUDGE POND
0.252
TAILINGS POND
MINE RECLAMATION
TO DISCHARGE

◇	WASTE STREAM
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	WET TAILINGS
14	STEAM VENTS
15	WET TAILINGS
16	VENTS
17	WASTEWATER
18	NET COKE
19	EMISSIONS
20	SULPHUR
21	SWS WASTEWATER
22	CONDENSATE
23	FLUE GAS
24	BLOWDOWN
25	BLOWDOWN
26	FLUE GAS
27	FLY ASH
28	PRESCRUBBER BD
29	FGD BYPRODUCT
30	FLUE GAS
31	BOTTOM ASH
32	FLY ASH
33	ASH SLUICE BD
34	PRESCRUBBER BD
35	FGD BYPRODUCT
36	FLUE GAS
37	BLOWDOWN
38	SOFTENER SOLIDS
39	REGENERANT WASTE
40	EMISSIONS
41	TANK BOTTOMS
42	CONDENSATE
43	WASHDOWN
44	INPLANT RUNOFF
45	CLEAN RUNOFF
46	ALUM SLUDGE
47	EFFLUENT
48	DIGESTED SLUDGE
49	COKE SLUICE BD
50	BLOCK RUNOFF
51	INCINERATOR EMIS
52	NONCOMBUSTIBLES

FIGURE 3-2 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION I HOT WATER EXTRACTION/FLUID COKING/
CO & COKE BOILERS
MONENCO CONSULTANTS LIMITED

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MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m^3/sd	TEMP. °C	DENSITY kg/m^3	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3	TKN	NO_3
MINING	DEWATERING	SHALLOW AQUIFER	3	1710		1000	7.6						295 504						7 12
		BASAL AQUIFER	4	6700		1005	7.4						1440 9648						
		MINE WATER	5	5656		1000	8.3			12 67.9							.28 1.58		
	OVERBURDEN	MUSKEG RUNOFF	8	925		1000	7.3		34 31.4	8 7.4		64.6 59.7	78.7 72.8					.35 .324	
		SUBSOIL RUNOFF	9	2186		1000	7.6				30 65.6								
EXTRACTION	HWE/FILTRATION	FILTRATE	15	1.90E5	65	1015	8												
UPGRADING	DILUENT RECOVERY	WASTEWATER	17	2419	88	1000										TRACE	TRACE		
	GASIFICATION	WASTEWATER	18	912		1000	7.9		4050 3694			1252 1142				5 4.56	144 131		3 2.74
	SOUR WATER STRIPPER	SWS WASTEWATER	22	4200	140	1000	8.1		295 1239		204 857					5 21	50 210		
	HYDROGEN PLANT	CONDENSATE	24	2472		1000								TRACE	19 47				
	UPGRADING STEAM	BLOWDOWN	26	310	174	1000	9.5												
UTILITIES	BOILER PLANT	BLOWDOWN	27	386	174	1000	9.5					400 154							
	CO BOILERS	PRESCRUBBER BD	30	1550		1000													
		FGD BYPRODUCT [1]	31	572	45	1020		7.71E5 4.41E6											
	COOLING TOWER	BLOWDOWN	34	6240	24	1000	7.5				50 312	50 312					10 62.4		
	WATER T'MENT PLANT	REGENERANT WASTE	36	2100		1000	7						145 305						
OFFSITES	TANKAGE	TANK BOTTOMS	38	41		1100		4.33E5 1.76E4											
	CONDENSATE LEAKAGE	CONDENSATE	39	259		1000						400 104							
	BUILDING DRAINS	WASHDOWN	40	1308		1000	8.1						158 207				.12 .157	1.2 1.57	.046 .06
	SURFACE RUNOFF	INPLANT RUNOFF	41	4489		1000	7.6		511 2292	10 44.9	74.1 333	90 404						7.07 31.7	3.17 14.2
		CLEAN RUNOFF	42	653		1000	7.6		511 333		74.1 48.4							7.07 4.62	3.17 2.07
	POTABLE WATER T'MENT	ALUM SLUDGE	43	60		1000		9.70E5 5.82E4											
	SEWAGE TREATMENT	EFFLUENT	44	1140		1000					25 28.5								
		DIGESTED SLUDGE	45	9		1022		9.49E5 8654											
	SULPHUR STORAGE	BLOCK RUNOFF	46	39		1000	6												

WASTE STREAM	◇	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	SOLVENT	OIL & GREASE	PHENOL	DEA	SO_4	SULPHIDES	S_2O_3	PO_4
SHALLOW AQUIFER	3			467 799									11 18.8			
BASAL AQUIFER	4			3778 2.53E4									55 369	23.5 157		
MINE WATER	5		6.5 36.8	400 2262						3 17						
MUSKEG RUNOFF	8		365 338	10 9.25									.1 .092			
SUBSOIL RUNOFF	9		6123 1.34E4	150 328												
FILTRATE	15		4.06E4 7.73E6			1440 2.74E5		205 3.90E4								
WASTEWATER	17									TRACE						
WASTEWATER	18						32.5 29.6				730 666		120 109			3.5 3.19
SWS WASTEWATER	22		10 42								12 50.4		33 139		150 630	
CONDENSATE	24						TRACE									
BLOWDOWN	26			120 37.2												
BLOWDOWN	27		150 57.9	2500 966												
PRESCRUBBER BD	30		321 497													
FGD BYPRODUCT [1]	31															
BLOWDOWN	34		160 998	725 4524						10 62.4			290 1810			TRACE
REGENERANT WASTE	36			6490 1.36E4									3741 7856			
TANK BOTTOMS	38	9.13E4 3717								5.75E5 2.34E4						
CONDENSATE	39		1000 259	2500 648						1000 259						
WASHDOWN	40		1000 1308	200 262						1000 1308	3 3.92	270 353	15.1 19.8	32 41.9		1.05 1.37
INPLANT RUNOFF	41		1170 5252	350 1571						200 898	.025 .112					1.6 7.18
CLEAN RUNOFF	42		660 431	200 131												
ALUM SLUDGE	43		3.00E4 1800													
EFFLUENT	44		25 28.5							25 28.5						
DIGESTED SLUDGE	45		5.11E4 466													
BLOCK RUNOFF	46		200 7.82												TRACE	

WASTE STREAM	◇	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al
SHALLOW AQUIFER	3	34 58.1				68 116	24 41		72 123	3 5.13	
BASAL AQUIFER	4	1060 7102				55 369	30 201		1137 7618		
MINE WATER	5		.23 1.3			99.7 564	24.8 140	.31 1.75	66 373	2.07 16.2	
MUSKEG RUNOFF	8	1.7 1.57	.06 .055			16.5 15.3	4.5 4.16		4.9 4.53	.5 .462	
SUBSOIL RUNOFF	9	10 21.9				15 32.8	5 10.9		15 32.8		
FILTRATE	15										
WASTEWATER	17										
WASTEWATER	18			.4 .365	31 28.3						
SWS WASTEWATER	22	117 491		.1 .42	.36 1.51	9 37.8					
CONDENSATE	24										
BLOWDOWN	26	9 2.79							14 4.34		
BLOWDOWN	27					500 193					
PRESCRUBBER BD	30										
FGD BYPRODUCT [1]	31										
BLOWDOWN	34	30 187				170 1061	40 250	.24 1.5	95 593	8 49.9	1.84 11.5
REGENERANT WASTE	36	481 1010				460 966	138 290		1398 2936	25 52.5	
TANK BOTTOMS	38										
CONDENSATE	39					150 38.9					
WASHDOWN	40	7.7 10.1	.11 .144			41.8 54.7	9 11.8		23.5 30.7	1.7 2.22	
INPLANT RUNOFF	41	52 233				15 67.3	5 22.4		15 67.3		
CLEAN RUNOFF	42	26 17				15 9.8	5 3.27		15 9.8		
ALUM SLUDGE	43										
EFFLUENT	44										
DIGESTED SLUDGE	45										
BLOCK RUNOFF	46										

[1] ALSO CONTAINS 19.2%wt NH_4HSO_3 AND 7.5%wt $(NH_4)_2SO_3$

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
34 8.1				68 116	24 41		72 123	3 5.13												6 10.3			
060 102				55 369	30 201		1137 7618					.9 6.03			.5 3.35								
	.23 1.3			99.7 564	24.8 140	.31 1.75	66 373	2.87 16.2			.19 1.07		.004 .023	.007 .04	.05 4.81		.021 .119	.011 .062		8.25 46.7	.39 2.21		.046 .26
.7 .57	.06 .055			16.5 15.3	4.5 4.16		4.9 4.53	.5 .462												2.2 2.03			
10 1.9				15 32.8	5 10.9		15 32.8																
		.4 .365	31 28.3																				
117 391		.1 .42	.36 1.51	9 37.8									.07 .294		8.8 37					2.6 10.9			
9 .79							14 4.34													6 1.86			
				500 193																35 13.5			
30 87				170 1061	40 250	.24 1.5	95 593	8 49.9	1.84 11.5		.64 3.99		.032 .2	TRACE	4.9 30.6	.2 1.25	.044 .275			36 225			
81 010				460 966	138 290		1398 2936	25 52.5												103 216			
				150 38.9																35 9.07			
.7 .1	.11 .144			41.8 54.7	9 11.8		23.5 30.7	1.7 2.22			.16 .209									12 15.7			
52 33				15 67.3	5 22.4		15 67.3												52 233				
6 7				15 9.8	5 3.27		15 9.8																

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L	500
LOADING kg/sd	1440

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

MATRIX 3-3

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 2 HOT WATER EXTRACTION/TAILINGS
FILTRATION/FLUID COKING/
GASIFICATION OF COKE

MONENCO CONSULTANTS LIMITED

5

AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m^3	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY
MINING	SITE PREPARATION	ASH	2	812		400		5000 4.06				5.90E4 47.9					
	OVERBURDEN	MUSKEG	6	3.05E7		840	7.6										
		SUBSOIL	7	1.72E8		1600	7.5								6.30E5 1.00E8	2.07E5 3.57E7	1.62E5 2.79E7
EXTRACTION	FEED SYSTEM	REJECTS	12	9.85E6	82	1484	8.5	1.19E5 1.17E6	1.50E4 1.40E5						8.37E5 8.24E6	8661 8.53E4	2.08E4 2.05E5
	HWE/FILTRATION	DRY TAILINGS	13	2.32E8	65	1600		1.30E5 3.23E7	1.07E4 2.40E6	1520 3.52E5					8.21E5 1.90E8	8500 1.97E6	2.04E4 4.73E6
UPGRADING	GASIFICATION	SLAG	19	3.26E5		723		1.10E4 2.97E4				8.72E5 2.85E5					
	SULPHUR PLANT	SULPHUR	21	1.07E6		2046		100 107				2 2.14					
UTILITIES	CO BOILERS	FLY ASH	29	5.42E4	430	2100	8.5										
	WATER T'MENT PLANT	SOFTENER SOLIDS	35	2.78E4		2040		4.00E5 1.11E4									
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	48	1663		4700						5.49E5 913					

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DA

AREA	PROCESS	WASTE STREAM	◇	FLOW m^3/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m^3	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3
MINING	SITE PREPARATION	EMISSIONS	1	2.63E4	400	101	1.25E6	1.12E5 2942	3.32E5 8724						7.87E5 2.07E4		
	FUGITIVE EMISSION	DUST *	10														
		DIESEL EMISSIONS	11	1.33E4	540	101	1.11E6		560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	330 4.4
EXTRACTION	HWE/FILTRATION	STEAM VENTS	14	1.89E6	200	101	7.62E5	7.62E5 1.44E6									
	FROTH TREATMENT	VENTS	16	1.14E4		101	1.47E6	7.72E4 882	798 9.12		2.58E5 2944				7.62E5 8703		
UPGRADING	SULPHUR PLANT	EMISSIONS	20	3.86E6	538	105	1.29E6	3.41E4 1.32E5	3.44E5 1.33E6			549 2123	10.2 39.4		9.12E5 3.52E6	211 816	
	OXYGEN PLANT	EMISSIONS	23	5291	20	101	1.19E6		716 3.79		2.34E4 124				1.15E6 6063		
	UPGRADING HEATERS	FLUE GAS	25	2.17E7	400	110	1.24E6	9.13E4 1.98E6	2.75E5 5.98E6		4.19E4 9.11E5	160 3475	2 43.4		8.19E5 1.78E7	270 5864	
UTILITIES	CO BOILERS	FLUE GAS	28	1.75E7	43	101	1.24E6	6.92E4 1.21E6	2.60E5 4.56E6		1.74E4 3.05E5	853 1.49E4	11 193		8.90E5 1.56E7	221 3872	TRACE
	PG BOILERS	FLUE GAS	32	1.27E7	177	101	1.31E6	7.90E4 1.01E6	4.26E5 5.42E6		3.78E4 4.81E5	51.4 654	.65 8.27		7.46E5 9.50E6	284 3615	
	WASTE HEAT BOILERS	FLUE GAS	32	1.01E7	177	101	1.15E6	1.40E5 1.41E6	1.73E5 1.74E6		2019 2.04E4				8.18E5 8.25E6	38.6 389	
	PG SUPERHEATERS	FLUE GAS	33	6.04E5	177	101	1.19E6	1.33E5 8.02E4	1.96E5 1.18E5		2.56E4 1.55E4	600 363	9 5.44		8.17E5 4.94E5	314 190	
	NG SUPERHEATERS	FLUE GAS	33	4.18E6	177	101	1.18E6	1.32E5 5.52E5	1.63E5 6.83E5		2.33E4 9.74E4				8.44E5 3.53E6	284 1188	
OFFSITES	FLARE	EMISSIONS	37	1.04E5	1000	101	1.19E6	1.32E5 1.37E4	1.95E5 2.02E4			600 62.3	8 .831		8.44E5 8.76E4		
	SOLID WASTE	INCINERATOR EMIS	47	1.78E4	650	103	1.23E6	1.22E5 2164	3.06E5 5444			122 2.16	1.5 .03		7.99E5 1.42E4	1105 19.6	

* NOT CHARACTERIZED

MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY	SPENT CA'LYST	TOTAL ORG.	TOTAL INORG.	LIME	$CaCO_3$	$CaSO_4$	METALS	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
			5.90E4 47.9														1.10E5 89.3					8.50E5 690	2.53E5 205				6.40E4 52		2.40E4 19.5		4.10E4 33.3	1.50E4 12.2			8.00E4 65				2.10E4 17.1			3.20E5 260	8000 6.5		
										9.76E5 2.98E7	2.40E4 7.32E5																																		
						6.30E5 1.08E8	2.07E5 3.57E7	1.62E5 2.79E7																																					
1.58E4 1.40E5						8.37E5 8.24E6	8661 8.53E4	2.08E4 2.05E5																																					
1.07E4 2.40E6	1520 3.52E5					8.21E5 1.90E8	8500 1.97E6	2.04E4 4.73E6																																					
			6.72E5 2.85E5																			9000 2938					9000 2938									4000 1306								1.58E4 4896	
			2 2.14																			15 16.1																	1.00E6 1.07E6						
																	3.31E5 1.79E4						3.31E4 1791				9.92E4 5374								8264 448							5.29E5 2.87E4			
													6.00E5 1.67E4																																
			5.49E5 913												4.51E5 758																														

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
3.32E5 8724						7.87E5 2.07E4			1.32E4 348		550 14.5				
560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	330 4.4	1.50E4 200		1.88E4 250	5.46E4 728		5110 68.1	2780 37.1
798 9.12		2.58E5 2944				7.62E5 8709			1.76E4 201				3.50E5 4003		
3.44E5 1.33E6			549 2123	10.2 39.4		9.12E5 3.52E6	211 816								
716 3.79		2.34E4 124				1.15E6 6063			1.93E4 102						
2.75E5 5.90E6		4.19E4 9.11E5	160 3475	2 43.4		8.19E5 1.78E7	270 5864		1.52E4 3.30E5						
2.68E5 4.56E6		1.74E4 3.05E5	853 1.49E4	11 193		8.90E5 1.56E7	221 3872	TRACE	5854 1.03E5		3.1 54.3				
4.26E5 5.42E6		3.78E4 4.81E5	51.4 654	.65 8.27		7.46E5 9.50E6	284 3615		1.45E4 1.85E5	.38 4.84					
1.73E5 1.74E6		2019 2.04E4				8.18E5 8.25E6	38.6 389		1.37E4 1.39E5	6.28 63.3					
1.96E5 1.10E5		2.56E4 1.55E4	600 363	9 5.44		8.17E5 4.94E5	314 190		1.95E4 1.18E4						
1.63E5 6.03E5		2.33E4 9.74E4				8.44E5 3.53E6	284 1188		1.42E4 5.93E4	5.97 25					
1.95E5 2.02E4			600 62.3	8 .831		8.44E5 8.76E4			1.42E4 1471						
3.06E5 5444			122 2.16	1.5 .03		7.99E5 1.42E4	1105 19.6				123 2.19				

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.08E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS NOTED OTHERWISE

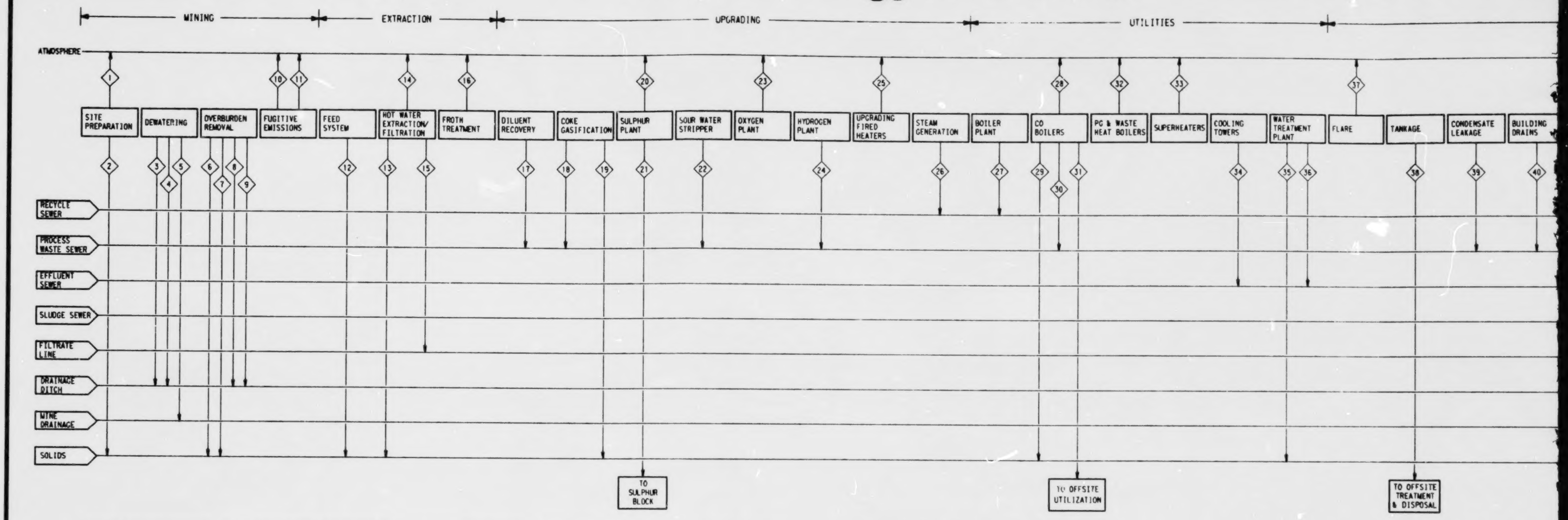
DATA PRESENTATION: GASES

PARAMETER	CO_2
CONCENTRATION mg/m³	4000
LOADING kg/sd	1.42E6

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-4

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION 2 HOT WATER EXTRACTION/TAILINGS FILTRATION/FLUID COKING/ GASIFICATION OF COKE
MONENCO CONSULTANTS LIMITED


MINING
EXTRACTION
UPGRADING
UTILITIES
ATMOSPHERE
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
HOT WATER EXTRACTION/ FILTRATION
FROTH TREATMENT
DILUENT RECOVERY
COKE GASIFICATION
SULPHUR PLANT
SOUR WATER STRIPPER
OXYGEN PLANT
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
BOILER PLANT
CO BOILERS
PC & WASTE HEAT BOILERS
SUPERHEATERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
FILTRATE LINE
DRAINAGE DITCH
MINE DRAINAGE
SOLIDS
TO SULPHUR BLOCK
TO OFFSITE UTILIZATION
TO OFFSITE TREATMENT & DISPOSAL
1
2
3
4
5
6
7
8
9
10
11
12
13
14
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16
17
18
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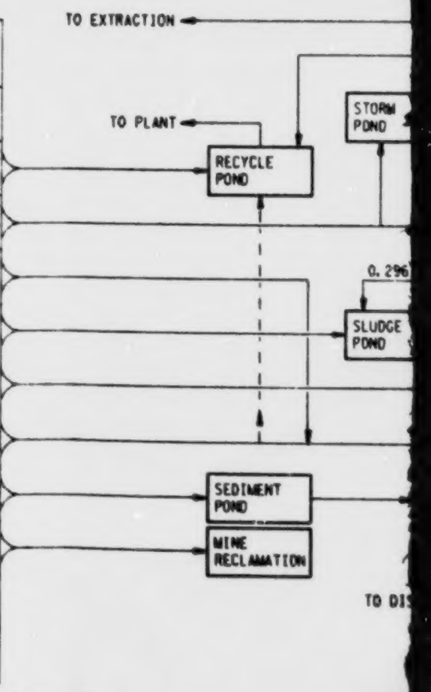
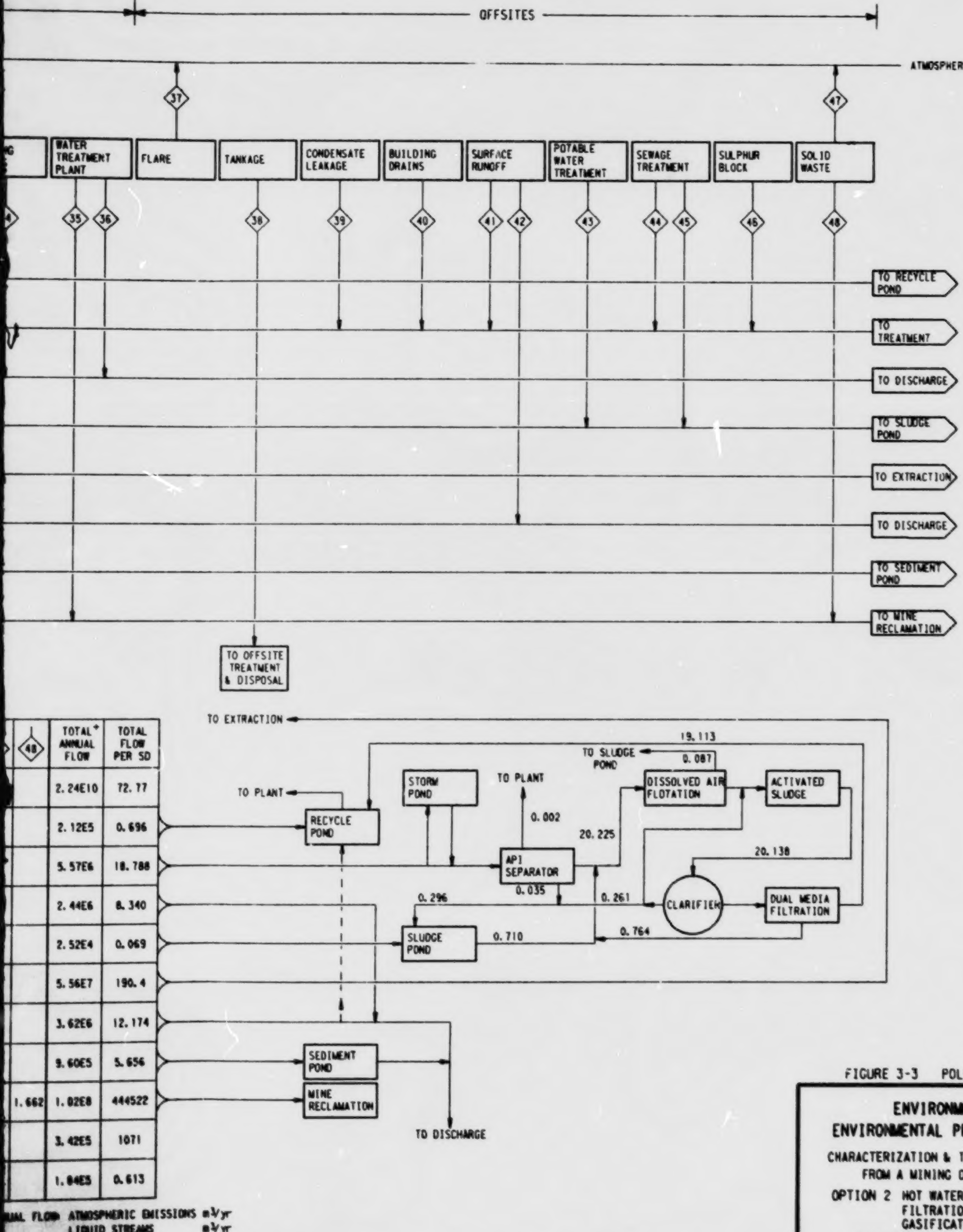
40

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	TOTAL+ ANNUAL FLOW	TOTAL FLOW PER SD
ATMOSPHERIC EMISSIONS $10^6 m^3/sd$	0.026									✱	0.013			1.892		0.011				3.864			0.005		21.72			17.52				22.81	4.786				0.104										0.018		2.24E10	72.77
RECYCLE SEWER $10^3 m^3/sd$																										0.310	0.386																						2.12E5	0.696
PROCESS WASTE SEWER $10^3 m^3/sd$																	2.419	0.912				4.200		2.472						1.550									0.259	1.308	4.489			1.140		0.039			5.57E6	18.788
EFFLUENT SEWER $10^3 m^3/sd$																																		6.240		2.100													2.44E6	8.340
SLUDGE SEWER $10^3 m^3/sd$																																											0.060		0.009				2.52E4	0.069
FILTRATE LINE $10^3 m^3/sd$															190.4																																		5.56E7	190.4
DRAINAGE DITCH $10^3 m^3/sd$			1.710	6.700				0.925	2.186																																	0.653							3.62E6	12.174
MINE DRAINAGE $10^3 m^3/sd$					5.656																																												9.60E5	5.656
SOLIDS t/sd		0.812				30500	172000					9845	231820						326.4										54.2						27.84													1.662	1.02E8	444522
OTHER SOLIDS t/sd																					1071																												3.42E5	1071
OTHER LIQUIDS $10^3 m^3/sd$																															0.572							0.041											1.84E5	0.613


TO EXTRACTION
TO PLANT
STORM POND
RECYCLE POND
0.296
SLUDGE POND
SEDIMENT POND
MINE RECLAMATION
TO DIS

✱ NOT QUANTIFIED

+ UNITS FOR TOTAL ANNUAL FLOW: ATMOSPHERIC EMISSIONS m^3/yr
LIQUID STREAMS m^3/yr
SOLIDS t/yr


OFFSITES
ATMOSPHERE
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
SULPHUR BLOCK
SOLID WASTE
35
36
37
38
39
40
41
42
43
44
45
46
47
48
TO RECYCLE POND
TO TREATMENT
TO DISCHARGE
TO SLUDGE POND
TO EXTRACTION
TO DISCHARGE
TO SEDIMENT POND
TO MINE RECLAMATION
TO OFFSITE TREATMENT & DISPOSAL
TO EXTRACTION
TO PLANT
RECYCLE POND
STORM POND
TO PLANT
0.002
API SEPARATOR
0.035
20.225
TO SLUDGE POND
0.087
19.113
DISSOLVED AIR FLOTATION
ACTIVATED SLUDGE
20.138
CLARIFIER
DUAL MEDIA FILTRATION
0.296
0.261
SLUDGE POND
0.710
0.764
SEDIMENT POND
MINE RECLAMATION
TO DISCHARGE

48	TOTAL+ ANNUAL FLOW	TOTAL FLOW PER SD
	2.24E10	72.77
	2.12E5	0.696
	5.57E6	18.788
	2.44E6	8.340
	2.52E4	0.069
	5.56E7	190.4
	3.62E6	12.174
	9.60E5	5.656
1.662	1.02E8	444522
	3.42E5	1071
	1.84E5	0.613

UAL FLOW ATMOSPHERIC EMISSIONS m³/yr
LIQUID STREAMS m³/yr
SOLIDS t/yr

◇	WASTE STREAM
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	DRY TAILINGS
14	STEAM VENTS
15	FILTRATE
16	VENTS
17	WASTEWATER
18	WASTEWATER
19	SLAG
20	EMISSIONS
21	SULPHUR
22	SWS WASTEWATER
23	EMISSIONS
24	CONDENSATE
25	FLUE GAS
26	BLOWDOWN
27	BLOWDOWN
28	FLUE GAS
29	FLY ASH
30	PRESCRUBBER BD
31	FGD BYPRODUCT
32	FLUE GAS
33	FLUE GAS
34	BLOWDOWN
35	SOFTENER SOLIDS
36	REGENERANT WASTE
37	EMISSIONS
38	TANK BOTTOMS
39	CONDENSATE
40	WASHDOWN
41	INPLANT RUNOFF
42	CLEAN RUNOFF
43	ALUM SLUDGE
44	EFFLUENT
45	DIGESTED SLUDGE
46	BLOCK RUNOFF
47	INCINERATOR EMIS
48	NONCOMBUSTIBLES

FIGURE 3-3 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION 2 HOT WATER EXTRACTION/TAILINGS
FILTRATION/FLUID COKING/
GASIFICATION OF COKE
MONENCO CONSULTANTS LIMITED

N00127.PFD F24

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AREA	PROCESS	WASTE STREAM	◇	FLOW m^3/sd	TEMP. °C	DENSITY kg/m^3	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3
MINING	DEWATERING	SHALLOW AQUIFER	3	1710		1000	7.6						295 504				
		BASAL AQUIFER	4	6700		1005	7.4						1440 9648				
		MINE WATER	5	5656		1000	8.3			12 67.9							.28 1.58
	OVERBURDEN	MUSKEG RUNOFF	8	1661		1000	7.3		34 56.5	8 13.3		64.6 107	78.7 131				
		SUBSOIL RUNOFF	9	691		1000	7.6				30 20.7						
EXTRACTION	HOT WATER EXTRACTION	WET TAILINGS	13	3.25E5	65	1232	8.5	6.09E5 1.98E8									
	FROTH TREATMENT	WET TAILINGS	15	2.02E4	75	1079	8	8.31E5 1.67E7									
UPGRADING	DILUENT RECOVERY	WASTEWATER	17	2419	88	1000										TRACE	TRACE
	SOUR WATER STRIPPER	SWS WASTEWATER	22	5064	140	1000	8.1		295 1494		204 1033					5 25.3	50 253
	HYDROGEN PLANT	CONDENSATE	23	2462		1000								TRACE	19 46.8		
	UPGRADING STEAM	BLOWDOWN	25	312	174	1000	9.5										
UTILITIES	BOILER PLANT	BLOWDOWN	26	436	174	1000	9.5					400 175					
	COOLING TOWER	BLOWDOWN	29	6670	24	1000	7.5				50 334	50 334					10 66.7
	WATER T'MENT PLANT	REGENERANT WASTE	31	2370		1000	7						145 344				
OFFSITES	TANKAGE	TANK BOTTOMS	33	41		1100		4.33E5 1.76E4									
	CONDENSATE LEAKAGE	CONDENSATE	34	259		1000						400 104					
	BUILDING DRAINS	WASHDOWN	35	1308		1000	8.1						158 207				.12 .157
	SURFACE RUNOFF	INPLANT RUNOFF	36	4489		1000	7.6		511 2292	10 44.9	74.1 333	90 404					
		CLEAN RUNOFF	37	653		1000	7.6		511 333		74.1 48.4						
	POTABLE WATER T'MENT	ALUM SLUDGE	38	60		1000		9.70E5 5.82E4									
	SEWAGE TREATMENT	EFFLUENT	39	1140		1000					25 28.5						
		DIGESTED SLUDGE	40	9		1022		9.49E5 8654									
	SULPHUR STORAGE	BLOCK RUNOFF	41	40		1000	6										

WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

$_2$O	COD	TOC	BOD$_5$	TOTAL ALK.	HCO$_3$	H$_2$	CO$_2$	H$_2$S	NH$_3$	TKN	NO$_3$	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	SOLVENT	OIL & GREASE	PHENOL	DEA	SO$_4$	SULPHIDES	S$_2$O$_3$	PO$_4$	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
					295 504						7 12			467 799									11 18.8				34 58.1				68 116	24 41		72 123	3 5.13												6 10.3			
					1440 9648									3778 2.53E4									55 369	23.5 157			1060 7102				55 369	30 201		1137 7618					.9 6.03			.5 3.35								
		12 67.9							.28 1.58				6.5 36.8	400 2262						3 17								.23 1.3			99.7 564	24.8 140	.31 1.75	66 373	2.87 16.2			.19 1.07		.004 .023	.007 .04	.85 4.81		.021 .119	.011 .062		8.25 46.7	.39 2.21		.046 .26
	34 56.5	8 13.3		64.6 107	78.7 131					.35 .581			365 606	10 16.6									.1 .166				1.7 2.82	.06 .1			16.5 27.4	4.5 7.47		4.9 8.14	.5 .831												2.2 3.65			
			30 20.7										6123 4232	150 104													10 6.91				15 10.4	5 3.46		15 10.4																
E5 E8													6.17E5 2.00E8			6776 2.20E6																																		
E5 E7													2.02E5 4.06E6			2.70E4 5.43E5		1.94E4 3.91E5																																
								TRACE	TRACE											TRACE																														
	295 1494		204 1033					5 25.3	50 253				10 50.6								12 60.8		33 167		150 760		117 592		.1 .506	.36 1.82	9 45.6									.07 .354		8.8 44.6					2.6 13.2			
						TRACE	19 46.8										TRACE																																	
														120 37.4													9 2.81							14 4.37													6 1.87			
				400 175									150 65.4	2500 1091																	500 218																35 15.3			
			50 334	50 334					10 66.7				160 1067	725 4836						10 66.7			290 1934			TRACE	30 200				170 1134	40 267	.24 1.6	95 634	8 53.4	1.84 12.3		.64 4.27		.032 .213	TRACE	4.9 32.7	.2 1.33	.044 .293			36 240			
					145 344									6490 1.54E4									3741 8866				481 1140				460 1090	138 327		1398 3313	25 59.3												103 244			
E5 E4												9.13E4 3717								5.75E5 2.34E4																														
				400 104									1000 259	2500 648						1000 259											150 38.9																35 9.07			
					158 207				.12 .157	1.2 1.57	.046 .06		1000 1308	200 262						1000 1308	3 3.92	270 353	15.1 19.8	32 41.9		1.05 1.37	7.7 10.1	.11 .144			41.8 54.7	9 11.8		23.5 30.7	1.7 2.22			.16 .209									12 15.7			
	511 2292	10 44.9	74.1 333	90 404						7.07 31.7	3.17 14.2		1170 5252	350 1571						200 898	.025 .112					1.6 7.18	52 233				15 67.3	5 22.4		15 67.3												52 233				
	511 333		74.1 48.4							7.07 4.62	3.17 2.07		660 431	200 131													26 17				15 9.8	5 3.27		15 9.8																
E5 E4													3.00E4 1800																																					
			25 28.5										25 28.5							25 28.5																														
E5 4													5.11E4 466																																					
													200 8.04												TRACE																									

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L	500
LOADING kg/sd	1440

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-5

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 3 HOT WATER EXTRACTION/FLEXICOKING/
FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED

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MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY	SPENT CA'LYST	TOTAL ORG.	TOTAL INORG.
MINING	SITE PREPARATION	ASH	2	812		400		5000 4.06				5.90E4 47.9								
	OVERBURDEN	MUSKEG	6	3.05E7		840	7.6												9.76E5 2.98E7	2.40E4 7.32E5
		SUBSOIL	7	1.72E8		1600	7.5								6.30E5 1.08E8	2.07E5 3.57E7	1.62E5 2.79E7			
EXTRACTION	FEED SYSTEM	REJECTS	12	9.85E6	82	1484	8.5	1.19E5 1.17E6	1.50E4 1.48E5						8.37E5 8.24E6	8661 8.53E4	2.08E4 2.05E5			
UPGRADING	FLEXICOKING	CHAR	18	6.36E5				7.79E4 4.96E4				1.12E5 7.14E4	7.85E5 4.99E5							
		COKE FINES	19	9.86E4		1180		1.00E5 9860					9.00E5 8.87E4							
	SULPHUR PLANT	SULPHUR	21	1.11E6		2046		100 111				2 2.23								
UTILITIES	WATER T'MENT PLANT	SOFTENER SOLIDS	30	3.15E4		2040		4.00E5 1.26E4												
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	43	1663		4700						5.49E5 913								

AREA	PROCESS	WASTE STREAM	◇	LIME	$CaCO_3$	$CaSO_4$	METALS	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo
MINING	SITE PREPARATION	ASH	2						1.10E5 89.3					8.50E5 690	2.53E5 205				6.40E4 52		2.40E4 19.5		4.10E4 33.3	1.50E4 12.2	
	OVERBURDEN	MUSKEG	6																						
		SUBSOIL	7																						
EXTRACTION	FEED SYSTEM	REJECTS	12																						
UPGRADING	FLEXICOKING	CHAR	18					1.9 1.21	6512 4142	83 52.8		74 47.1			1520 967	17 10.8	55 35	18 11.4	6485 4124	4640 2951	5074 3227		695 442	91 57.9	204 130
		COKE FINES	19																						
	SULPHUR PLANT	SULPHUR	21											15 16.7											
UTILITIES	WATER T'MENT PLANT	SOFTENER SOLIDS	30		6.00E5 1.89E4																				
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	43				4.51E5 750																		

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m³	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
MINING	SITE PREPARATION	EMISSIONS	1	2.63E4	400	101	1.25E6	1.12E5 2942	3.32E5 8724						7.87E5 2.07E4			1.32E4 348		550 14.5				
	FUGITIVE EMISSION	DUST *	10																					
		DIESEL EMISSIONS	11	1.33E4	540	101	1.11E6		560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	330 4.4	1.50E4 200		1.88E4 250	5.46E4 728		5110 68.1	2780 37.1
EXTRACTION	HOT WATER EXTRACTION	STEAM VENTS	14	1.89E6	200	101	7.62E5	7.62E5 1.44E6																
	FROTH TREATMENT	VENTS	16	1.14E4		101	1.47E6	7.72E4 882	798 9.12		2.58E5 2944				7.62E5 8709			1.76E4 201				3.50E5 4003		
UPGRADING	SULPHUR PLANT	EMISSIONS	20	3.55E6	538	105	1.25E6	3.68E4 1.31E5	2.25E5 7.99E5			592 2102	10.2 36.2		9.83E5 3.49E6	211 751								
	UPGRADING HEATERS	FLUE GAS	24	2.19E7	400	110	1.24E6	9.13E4 2.00E6	2.75E5 6.04E6		4.19E4 9.20E5	160 3510	2 43.9		8.19E5 1.80E7	270 5924		1.52E4 3.33E5						
UTILITIES	PG BOILERS	FLUE GAS	27	4.84E7	177	101	1.22E6	9.96E4 4.82E6	2.39E5 1.16E7		2.86E4 1.39E6	910 4.41E4	12 581		8.45E5 4.09E7	120 5812		9363 4.54E5	1.5 72.7					
	NG SUPERHEATERS	FLUE GAS	28	4.10E6	177	101	1.18E6	1.32E5 5.42E5	1.63E5 6.70E5		2.33E4 9.55E4				8.44E5 3.46E6	284 1164		1.42E4 5.82E4	5.97 24.5					
OFFSITES	FLARE	EMISSIONS	32	1.04E5	1000	101	1.19E6	1.32E5 1.37E4	1.95E5 2.02E4			600 62.3	8 .831		8.44E5 8.76E4			1.42E4 1471						
	SOLID WASTE	INCINERATOR EMIS	42	1.78E4	650	103	1.23E6	1.22E5 2164	3.06E5 5444			122 2.16	1.5 .027		7.99E5 1.42E4	1105 19.6				123 2.19				

* NOT CHARACTERIZED

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E

UNITS AS ABOVE UNLESS NOTED OTHERWISE

Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
		6.40E4 52		2.40E4 19.5		4.10E4 33.3	1.50E4 12.2			8.00E4 65				2.10E4 17.1			3.20E5 260	8000 6.5		
55 35	18 11.4	6485 4124	4640 2951	5074 3227		695 442	91 57.9	204 130	4824 3068	891 567	1633 1039	174 111	6 3.82	1.51E4 9616				1985 1262	7430 4725	31 19.7
														1.00E6 1.11E6						

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

DATA PRESENTATION: GASES

PARAMETER	CO_2
CONCENTRATION mg/m^3	4000
LOADING kg/sd	1.42E6

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

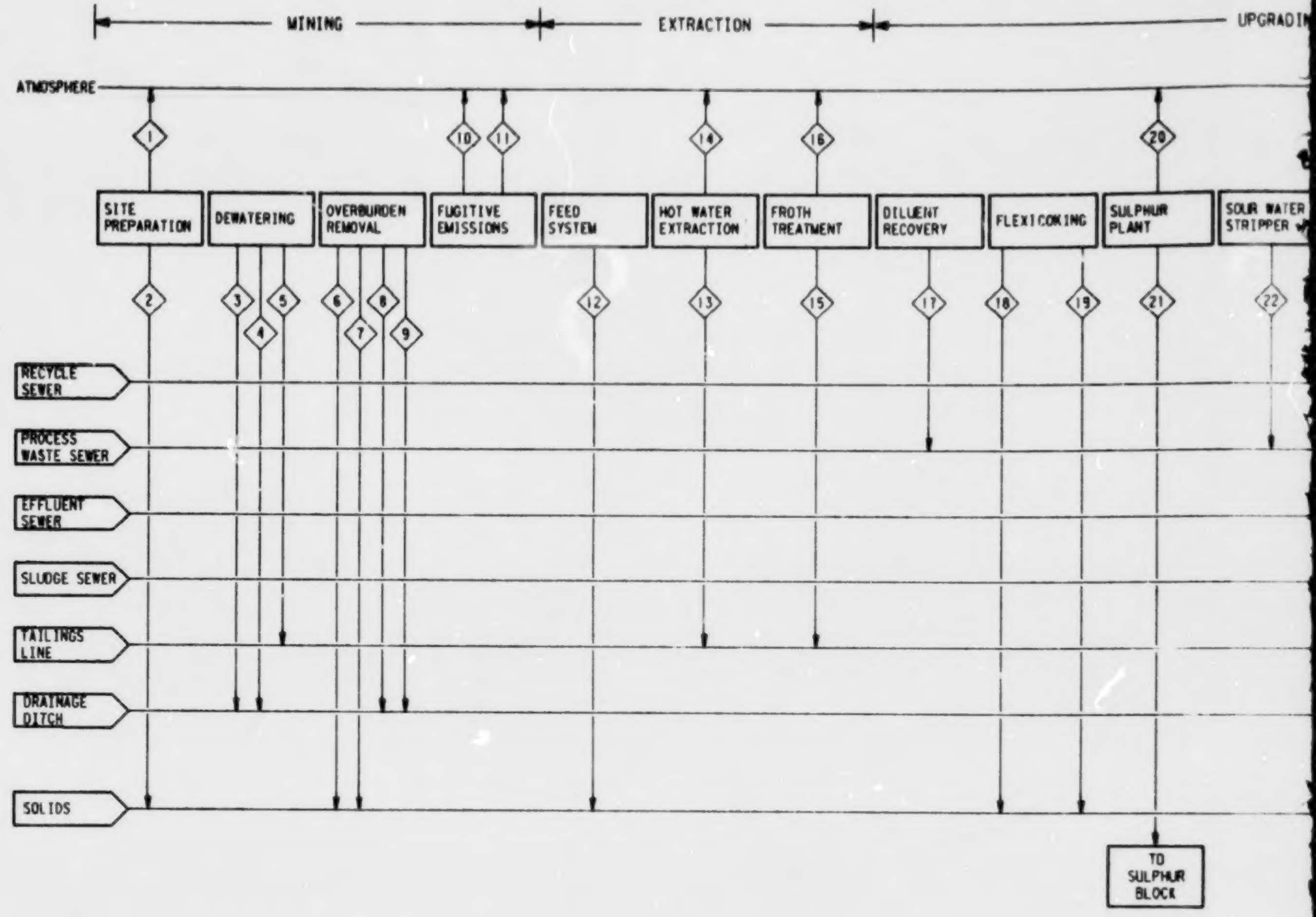
MATRIX 3-6

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

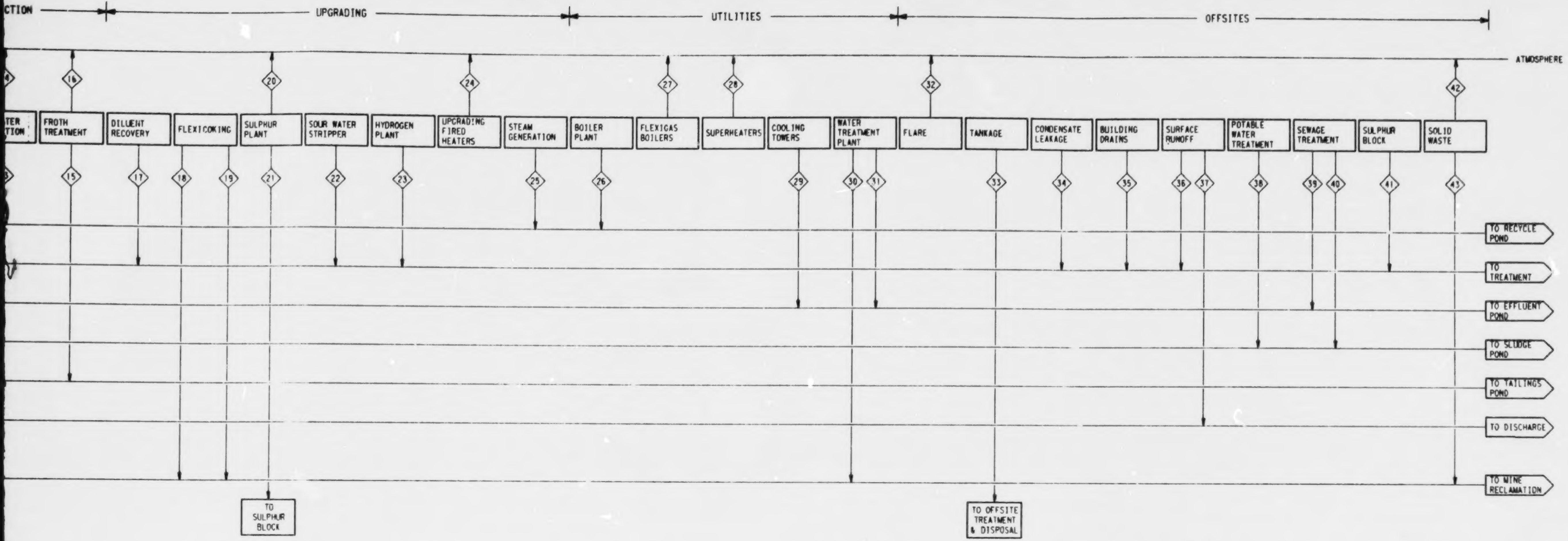
OPTION 3 HOT WATER EXTRACTION/FLEXICOKING/
FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED


MINING
EXTRACTION
UPGRADIN
ATMOSPHERE
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
HOT WATER EXTRACTION
FROTH TREATMENT
DILUENT RECOVERY
FLEXICOKING
SULPHUR PLANT
SOUR WATER STRIPPER
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
TAILINGS LINE
DRAINAGE DITCH
SOLIDS
TO SULPHUR BLOCK
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱	⑲	⑳	㉑	㉒	㉓	㉔	㉕	㉖
ATMOSPHERIC EMISSIONS $10^6 m^3/sd$	0.026									✱	0.013			1.893		0.011				3.552				21.94		
RECYCLE SEWER $10^3 m^3/sd$																									0.312	0.43
PROCESS WASTE SEWER $10^3 m^3/sd$																	2.419					5.064	2.462			
EFFLUENT SEWER $10^3 m^3/sd$																										
SLUDGE SEWER $10^3 m^3/sd$																										
TAILINGS LINE $10^3 m^3/sd$					5.656								325.1		20.15											
DRAINAGE DITCH $10^3 m^3/sd$			1.710	6.700				1.661	0.691																	
SOLIDS t/sd		0.812				30500	172000					9845						636	98.6							
OTHER SOLIDS t/sd																					1113					
OTHER LIQUIDS $10^3 m^3/sd$																										

✱ NOT QUANTIFIED


CTION
UPGRADING
UTILITIES
OFFSITES
ATMOSPHERE
TER
TION
FROTH TREATMENT
DILUENT RECOVERY
FLEXICOKING
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
BOILER PLANT
FLEXIGAS BOILERS
SUPERHEATERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
SULPHUR BLOCK
SOLID WASTE
14
16
20
24
27
28
32
42
15
17
18
19
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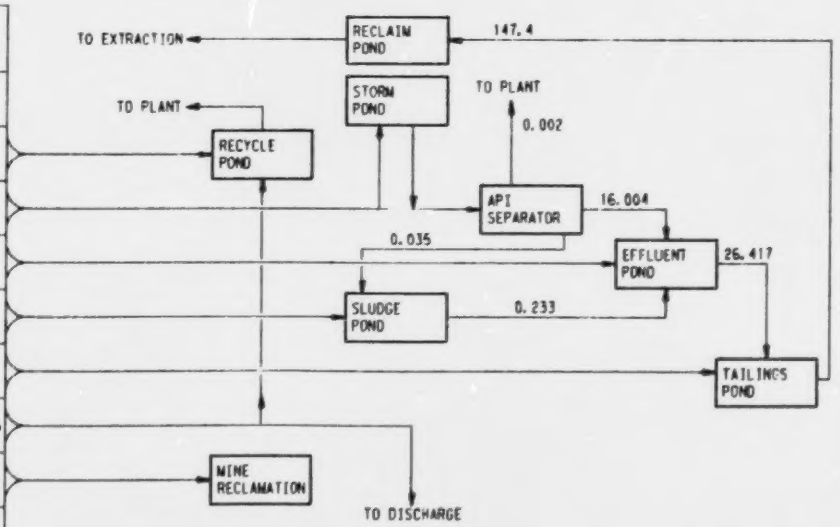
23
25
26
29
30
31
33
34
35
36
37
38
39
40
41
43
TO RECYCLE POND
TO TREATMENT
TO EFFLUENT POND
TO SLUDGE POND
TO TAILINGS POND
TO DISCHARGE
TO MINE RECLAMATION
TO SULPHUR BLOCK
TO OFFSITE TREATMENT & DISPOSAL

14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	TOTAL+ ANNUAL FLOW	TOTAL FLOW PER SD
1.893		0.011				3.552				21.94			48.44	4.100				0.104										0.018		2.41E10	80.10
											0.312	0.436																		2.27E5	0.748
			2.419					5.064	2.462											0.259	1.308	4.489					0.040			4.65E6	16.041
															6.670		2.370								1.140					3.06E6	10.180
																								0.060		0.009				2.52E4	0.069
	20.15																													1.02E8	350.9
																							0.653							3.45E6	11.415
				636	98.6											31.45													1.662	3.41E7	213114
							1113																							3.55E5	1113
																			0.041											1.23E3	0.041

+ UNITS FOR TOTAL ANNUAL FLOW: ATMOSPHERIC EMISSIONS m³/yr
LIQUID STREAMS m³/yr
SOLIDS t/yr


TO EXTRACTION
RECLAIM POND
147.4
STORM POND
TO PLANT
TO PLANT
0.002
RECYCLE POND
API SEPARATOR
16.004
0.035
EFFLUENT POND
26.417
SLUDGE POND
0.233
TAILINGS POND
MINE RECLAMATION
TO DISCHARGE

◇	WASTE STREAM
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	WET TAILINGS
14	STEAM VENTS
15	WET TAILINGS
16	VENTS
17	WASTEWATER
18	CHAR
19	COKE FINES
20	EMISSIONS
21	SULPHUR
22	SWS WASTEWATER
23	CONDENSATE
24	FLUE GAS
25	BLOWDOWN
26	BLOWDOWN
27	FLUE GAS
28	FLUE GAS
29	BLOWDOWN
30	SOFTENER SOLIDS
31	REGENERANT WASTE
32	EMISSIONS
33	TANK BOTTOMS
34	CONDENSATE
35	WASHDOWN
36	INPLANT RUNOFF
37	CLEAN RUNOFF
38	ALUM SLUDGE
39	EFFLUENT
40	DIGESTED SLUDGE
41	BLOCK RUNOFF
42	INCINERATOR EMIS
43	NONCOMBUSTIBLES

FIGURE 3-4 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 3 HOT WATER EXTRACTION/
FLEXICOKING/FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED

M00123.PFD F24

WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m^3/sd	TEMP. °C	DENSITY kg/m^3	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3	TKN	NO_3	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	SOLVENT	OIL & GREASE	PHENOL	DEA	SO_4	SULPHIDES	S_2O_3	PO_4	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K
MINING	DEWATERING	SHALLOW AQUIFER	3	1440		1000	7.6						295 427						7 10.1			467 676									11 15.9				34 49.2				68 98.5	24 34.8		72 104	3 4.34
		BASAL AQUIFER	4	6700		1005	7.4						1440 9648									3778 2.53E4									55 369	23.5 157			1060 7102				55 369	30 201		1137 7618	
		MINE WATER	5	4784		1000	8.3			12 57.4							.28 1.34				6.5 31.1	400 1914						3 14.4								.23 1.1			99.7 477	24.8 119	.31 1.48	66 316	2.87 13.7
	OVERBURDEN	MUSKEG RUNOFF	8	1515		1000	7.3		34 51.5	8 12.1		64.6 97.9	78.7 119					.35 .53			365 553	10 15.1									.1 .151				1.7 2.58	.06 .091			16.5 25	4.5 6.82		4.9 7.42	.5 .758
		SUBSOIL RUNOFF	9	562		1000	7.6				30 16.9										6123 3442	150 84.3													10 5.62				15 8.43	5 2.81		15 8.43	
EXTRACTION	HOT WATER EXTRACTION	WET TAILINGS	13	2.75E5	65	1232	8.5	6.09E5 1.67E8													6.17E5 1.70E8		6.17E5 1.70E8	6776 1.86E6																			
	FROTH TREATMENT	WET TAILINGS	15	1.71E4	75	1079	8	8.31E5 1.42E7													2.02E5 3.44E6		2.02E5 3.44E6	2.70E4 4.60E5		1.94E4 3.31E5																	
UPGRADING	DILUENT RECOVERY	WASTEWATER	17	2050	88	1000										TRACE	TRACE											TRACE															
	SOUR WATER STRIPPER	SWS WASTEWATER	22	2808	140	1000	8.1		295 828		204 573					5 14	50 140				10 28.1								12 33.7		33 92.7		150 421		117 329		.1 .281	.36 1.01	9 25.3				
	HYDROGEN PLANT	CONDENSATE	23	3415		1000								TRACE	19 64.9										TRACE																		
	UPGRADING STEAM	BLOWDOWN	25	231	174	1000	9.5															120 27.7													9 2.08							14 3.23	
UTILITIES	BOILER PLANT	BLOWDOWN	26	378	174	1000	9.5					400 151									150 56.8	2500 946																	500 189				
	PITCH BOILERS	ASH SLUICE BD	29	366	71	1000	6.4			170 62.2								11.5 4.2			2060 753	775 283						10 3.66	.062 .023			.1 .037		2.18 .797					17.2 6.29	7.63 2.79	.44 .161	255 93.2	13.8 5.05
		PRESCRUBBER BD	31	639		1000															2262 1445																						
		FGD BYPRODUCT[1]	32	513	45	1052		7.71E5 3.96E5																																			
	COOLING TOWER	BLOWDOWN	35	4740	24	1000	7.5				50 237	50 237					10 47.4				160 758	725 3437						10 47.4			290 1375			TRACE	30 142				170 806	40 190	.24 1.14	95 450	8 37.9
	WATER T'MENT PLANT	REGENERANT WASTE	37	2055		1000	7						145 298									6490 1.33E4									3741 7688				481 988				460 945	138 284		1398 2873	25 51.4
OFFSITES	TANKAGE	TANK BOTTOMS	39	34		1100		4.33E5 1.49E4												9.13E4 3145								5.75E5 1.98E4															
	CONDENSATE LEAKAGE	CONDENSATE	40	259		1000						400 104									1000 259	2500 648						1000 259											150 38.9				
	BUILDING DRAINS	WASHDOWN	41	1308		1000	8.1						158 207				.12 .157	1.2 1.57	.046 .06		1000 1308	200 262						1000 1308	3 3.92	270 353	15.1 19.8	32 41.9		1.05 1.37	7.7 10.1	.11 .144			41.8 54.7	9 11.8		23.5 30.7	1.7 2.22
	SURFACE RUNOFF	INPLANT RUNOFF	42	4489		1000	7.6		511 2292	10 44.9	74.1 333	90 404						7.07 31.7	3.17 14.2		1170 5252	350 1571						200 898	.025 .112					1.6 7.18	52 233				15 67.3	5 22.4		15 67.3	
		CLEAN RUNOFF	43	653		1000	7.6		511 333		74.1 48.4							7.07 4.62	3.17 2.07		660 431	200 131													26 17				15 9.8	5 3.27		15 9.8	
	POTABLE WATER T'MENT	ALUM SLUDGE	44	60		1000		9.70E5 5.82E4													3.00E4 1800																						
	SEWAGE TREATMENT	EFFLUENT	45	1140		1000					25 28.5										25 28.5							25 28.5															
		DIGESTED SLUDGE	46	9		1022		9.49E5 8654													5.11E4 466																						
	PITCH STORAGE	PITCH RUNOFF	47	2		1000	7.8								1.8 .003						420 .785	210 .393						10 .019											38 .071	10 .019	2.8 .005		
	SULPHUR STORAGE	BLOCK RUNOFF	48	36		1000	6														200 7.17												TRACE										

[1] ALSO CONTAINS 19.2%wt NH_4HSO_3 AND 7.5%wt $(NH_4)_2SO_3$

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

D4	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
	34 49.2				68 98.5	24 34.8		72 104	3 4.34												6 8.69			
	1060 7102				55 369	30 201		1137 7618					.9 6.03			.5 3.35								
		.23 1.1			99.7 477	24.8 119	.31 1.48	66 316	2.87 13.7			.19 .909		.004 .019	.007 .033	.85 4.07		.021 .1	.011 .053		8.25 39.5	.39 1.87		.046 .22
	1.7 2.58	.06 .091			16.5 25	4.5 6.82		4.9 7.42	.5 .758												2.2 3.33			
	10 5.62				15 8.43	5 2.81		15 8.43																
	117 329		.1 .281	.36 1.01	9 25.3									.07 .197		8.8 24.7					2.6 7.3			
	9 2.08							14 3.23													6 1.39			
					500 189																35 13.2			
0 7					17.2 6.29	7.63 2.79	.44 .161	255 93.2	13.8 5.05	21.9 8.01	.08 .029	.75 .274	.25 .091	.049 .018	.2 .073	19.7 7.2	TRACE	.12 .044	.28 .102	.02 .007	66.2 24.2	.34 .124	.87 .318	.12 .044
CE	30 142				170 806	40 190	.24 1.14	95 450	8 37.9	1.84 8.72		.64 3.03		.032 .152	TRACE	4.9 23.2	.2 .948	.044 .209			36 171			
	481 988				460 945	138 284		1398 2873	25 51.4												103 212			
					150 38.9																35 9.07			
5 7	7.7 10.1	.11 .144			41.8 54.7	9 11.8		23.5 30.7	1.7 2.22			.16 .209									12 15.7			
	52 233				15 67.3	5 22.4		15 67.3												52 233				
	26 17				15 9.8	5 3.27		15 9.8																
					38 .071	10 .019	2.8 .005			.9 .002				.03				2.52 .005				.48 .001	1.8 .003	1.6 .003

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L LOADING kg/sd	500 1440

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-7

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 4 HOT WATER EXTRACTION/
H-OIL/PITCH BOILERS

MONENCO CONSULTANTS LIMITED

11

AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY
MINING	SITE PREPARATION	ASH	2	687		400		5000 3.44				5.90E4 40.5					
	OVERBURDEN	MUSKEG	6	2.58E7		840	7.6										
		SUBSOIL	7	1.46E8		1600	7.5								6.30E5 9.20E7	2.07E5 3.03E7	1.62E 2.37E
EXTRACTION	FEED SYSTEM	REJECTS	12	8.33E6	82	1484	8.5	1.19E5 9.90E5	1.50E4 1.25E5						8.37E5 6.97E6	8661 7.21E4	2.08 1.73E
UPGRADING	HYDROVISBREAKING	NET PITCH	18	9200		1070						1.44E5 1320					
		SPENT CATALYST	19	8640		4000											
	SULPHUR PLANT	SULPHUR	21	9.26E5		2046		100 92.6				2 1.85					
UTILITIES	PITCH BOILERS	BOTTOM ASH	28	4.05E4	80	2400	8										
		FLY ASH	30	1.59E5	430	2100	8.5										
	WATER T'MENT PLANT	SOFTENER SOLIDS	36	2.73E4		2040		4.00E5 1.09E4									
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	50	1663		4700						5.49E5 913					

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DA

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m³	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3
MINING	SITE PREPARATION	EMISSIONS	1	2.22E4	400	101	1.25E6	1.12E5 2489	3.32E5 7379						7.87E5 1.75E4		
	FUGITIVE EMISSION	DUST *	10														
		DIESEL EMISSIONS	11	1.33E4	540	101	1.11E6		560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	330 4.4
EXTRACTION	HOT WATER EXTRACTION	STEAM VENTS	14	1.60E6	200	101	7.62E5	7.62E5 1.22E6									
	FROTH TREATMENT	VENTS	16	9670		101	1.47E6	7.72E4 746	798 7.72		2.58E5 2491				7.62E5 7368		
UPGRADING	SULPHUR PLANT	EMISSIONS	20	2.82E6	538	105	1.20E6	3.98E4 1.12E5	9.30E4 2.62E5			634 1785	6.77 19.1		1.06E6 2.99E6	211 595	
	UPGRADING HEATERS	FLUE GAS	24	3.20E7	400	110	1.21E6	2.10E4 6.72E5	2.46E5 7.87E6		2.10E4 6.72E5	25 801	.1 3.2		8.37E5 2.68E7	270 8651	
UTILITIES	PITCH BOILERS	FLUE GAS	27	2.64E7	43	101	1.23E6	6.92E4 1.83E6	2.09E5 5.51E6		4.50E4 1.19E6	2279 6.01E4	28.8 760		8.91E5 2.35E7	626 1.65E4	TRACE
	WASTE HEAT BOILERS	FLUE GAS	33	7.63E6	177	101	1.16E6	1.40E5 1.07E6	1.73E5 1.32E6		3593 2.74E4				8.26E5 6.30E6	23.6 180	
	NG SUPERHEATERS	FLUE GAS	34	1.89E6	177	101	1.18E6	1.32E5 2.49E5	1.63E5 3.08E5		2.33E4 4.39E4				8.44E5 1.59E6	284 536	
OFFSITES	FLARE	EMISSIONS	38	8.62E4	1000	101	1.18E6	1.43E5 1.23E4	1.82E5 1.57E4			54 4.66	.7 .06		8.36E5 7.21E4		
	SOLID WASTE	INCINERATOR EMIS	49	1.78E4	650	103	1.23E6	1.22E5 2164	3.06E5 5444			122 2.16	1.5 .027		7.99E5 1.42E4	1105 19.6	

* NOT CHARACTERIZED

WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY	SPENT CA'LYST	TOTAL ORG.	TOTAL INORG.	LIME	$CaCO_3$	$CaSO_4$	METALS	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
5000 3.44				5.90E4 40.5														1.10E5 75.6					8.50E5 584	2.53E5 174				6.40E4 44		2.40E4 16.5		4.10E4 28.2	1.50E4 10.3			8.00E4 55				2.10E4 14.4			3.20E5 220	8000 5.5		
											9.76E5 2.52E7	2.40E4 6.19E5																																		
							6.30E5 9.20E7	2.07E5 3.03E7	1.62E5 2.37E7																																				
1.19E5 9.90E5	1.50E4 1.25E5						8.37E5 6.97E6	8661 7.21E4	2.08E4 1.73E5																																					
				1.44E5 1320																			7.26E5 6676						6.22E4 572		1.49E4 137				1.59E4 146		507 4.66			3.67E4 338					591 5.44	
										4.32E5 3732													1.84E5 1590					3000 25.9									5.60E4 484			4.60E4 397					1.87E5 1616	
100 92.6				2 1.85																			15 13.9																	1.00E6 9.26E5						
																		2.71E5 1.10E4						4.12E4 1669				8.60E4 3484		2.14E4 867		1.43E4 579	2600 105			9900 401	1.53E4 620	1100 44.6					4.30E5 1.74E4	3.70E4 1499	6.25E4 2532	
																		3.31E5 5.26E4						3.31E4 5257				9.92E4 1.58E4								8264 1314							5.29E5 8.41E4			
4.00E5 1.09E4														6.00E5 1.64E4																																
				5.49E5 913												4.51E5 750																														

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
1.12E5 2489	3.32E5 7379						7.87E5 1.75E4			1.32E4 294		550 12.2				
	560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	330 4.4	1.50E4 200		1.88E4 250	5.46E4 728		5110 68.1	2780 37.1
7.62E5 1.22E6																
7.72E4 746	798 7.72		2.58E5 2491				7.62E5 7368			1.76E4 170				3.50E5 3386		
3.98E4 1.12E5	9.30E4 2.62E5			634 1785	6.77 19.1		1.06E6 2.99E6	211 595								
2.10E4 6.72E5	2.46E5 7.87E6		2.10E4 6.72E5	25 801	.1 3.2		8.37E5 2.68E7	270 8651		1.52E4 4.87E5						
6.92E4 1.83E6	2.09E5 5.51E6		4.50E4 1.19E6	2279 6.01E4	28.8 760		8.91E5 2.35E7	626 1.65E4	TRACE	1.50E4 3.95E5	3 79.1	6.8 179				
1.40E5 1.07E6	1.73E5 1.32E6		3593 2.74E4				8.26E5 6.30E6	23.6 180		1.39E4 1.06E5	6.3 48.1					
1.32E5 2.49E5	1.63E5 3.08E5		2.33E4 4.39E4				8.44E5 1.59E6	284 536		1.42E4 2.68E4	5.97 11.3					
1.43E5 1.23E4	1.82E5 1.57E4			54 4.66	.7 .06		8.36E5 7.21E4			1.44E4 1239						
1.22E5 2164	3.06E5 5444			122 2.16	1.5 .027		7.99E5 1.42E4	1105 19.6				123 2.19				

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS NOTED OTHERWISE

DATA PRESENTATION: GASES

PARAMETER	CO_2
CONCENTRATION mg/m³	4000
LOADING kg/sd	1.42E6

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-8

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 4 HOT WATER EXTRACTION/
H-OIL/PITCH BOILERS

MONENCO CONSULTANTS LIMITED

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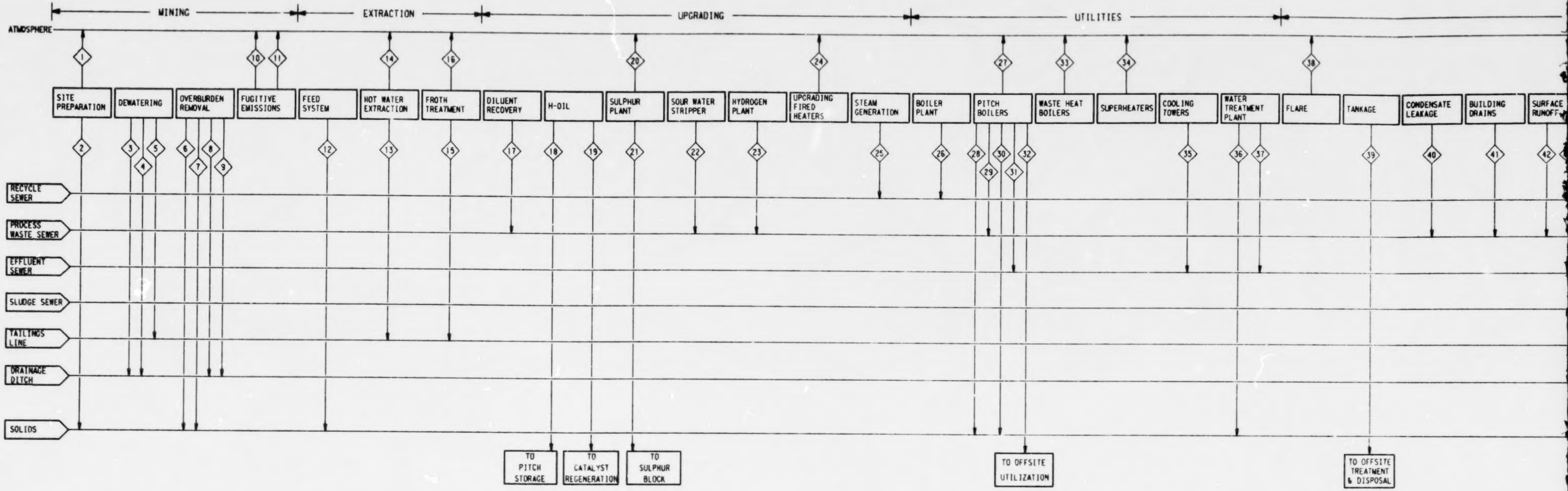
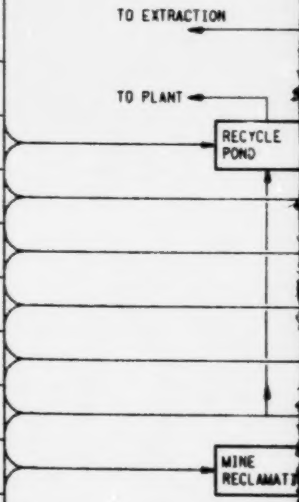
MONENCO CONSULTANTS LIMITED


MINING
EXTRACTION
UPGRADING
UTILITIES
ATMOSPHERE
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
HOT WATER EXTRACTION
FROTH TREATMENT
DILUENT RECOVERY
H-OIL
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
BOILER PLANT
PITCH BOILERS
WASTE HEAT BOILERS
SUPERHEATERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
TAILINGS LINE
DRAINAGE DITCH
SOLIDS
TO PITCH STORAGE
TO CATALYST REGENERATION
TO SULPHUR BLOCK
TO OFFSITE UTILIZATION
TO OFFSITE TREATMENT & DISPOSAL
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ATMOSPHERIC EMISSIONS $10^6m^3/sd$	0.022									*	0.013			1.601		0.010	
RECYCLE SEWER $10^3m^3/sd$																	
PROCESS WASTE SEWER $10^3m^3/sd$																	2.050
EFFLUENT SEWER $10^3m^3/sd$																	
SLUDGE SEWER $10^3m^3/sd$																	
TAILINGS LINE $10^3m^3/sd$					4.784								275.0		17.05		
DRAINAGE DITCH $10^3m^3/sd$			1.448	6.700				1.515	0.562								
SOLIDS t/sd		0.687				25800	146000					8329					
OTHER SOLIDS t/sd																	
OTHER LIQUIDS $10^3m^3/sd$																	

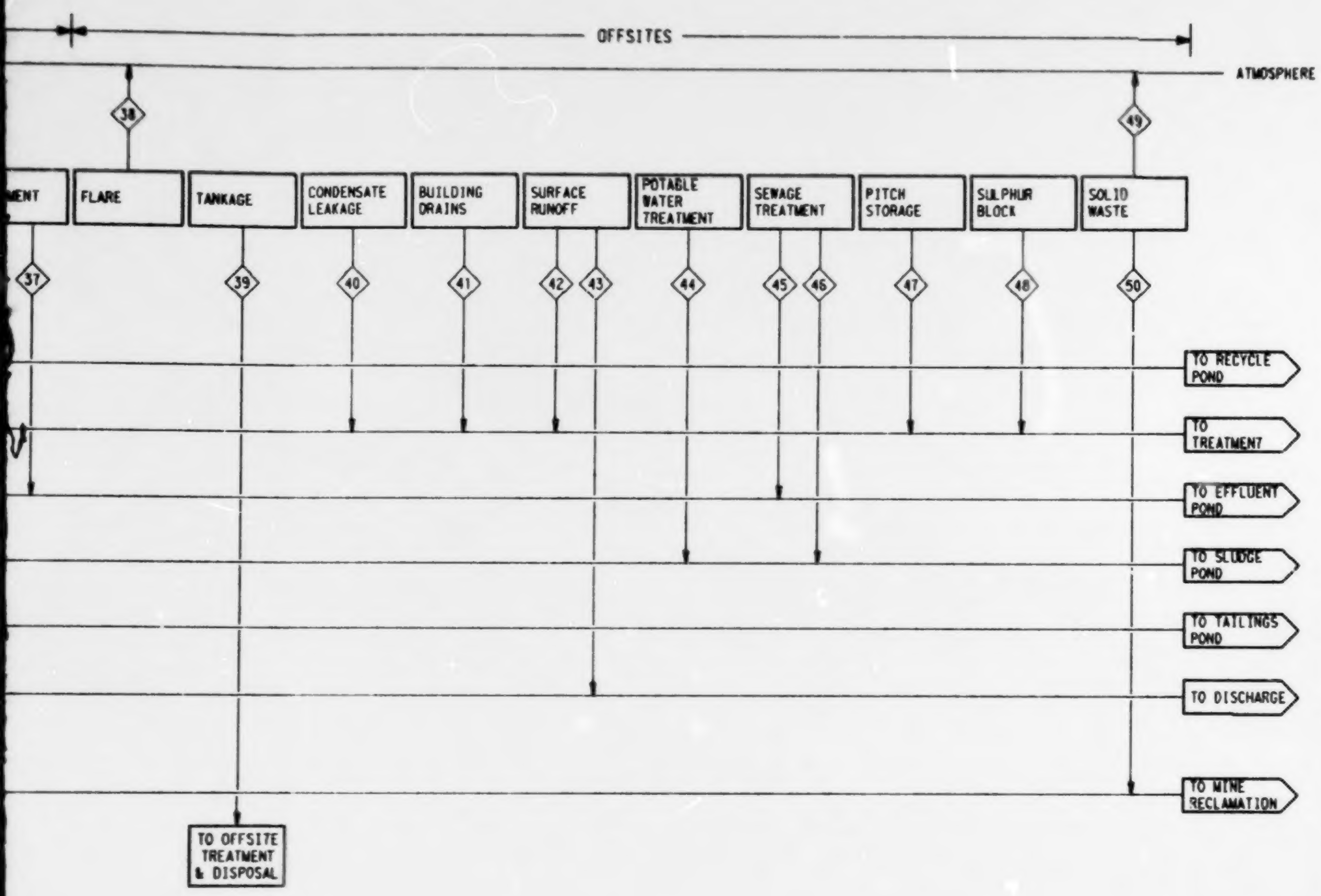
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
ATMOSPHERIC EMISSIONS $10^6m^3/sd$			2.816				32.04			26.38						7.628	1.886
RECYCLE SEWER $10^3m^3/sd$								0.231	0.378								
PROCESS WASTE SEWER $10^3m^3/sd$					2.808	3.415						0.366					
EFFLUENT SEWER $10^3m^3/sd$														0.639			
SLUDGE SEWER $10^3m^3/sd$																	
TAILINGS LINE $10^3m^3/sd$																	
DRAINAGE DITCH $10^3m^3/sd$																	
SOLIDS t/sd											40.51		159.0				
OTHER SOLIDS t/sd	9.20	8.64		926.3													
OTHER LIQUIDS $10^3m^3/sd$															0.513		

	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	TOTAL + ANNUAL FLOW	TOTAL FLOW PER SD
ATMOSPHERIC EMISSIONS $10^6m^3/sd$				0.086											0.018		2.21E10	72.50
RECYCLE SEWER $10^3m^3/sd$																	1.84E5	0.609
PROCESS WASTE SEWER $10^3m^3/sd$						0.259	1.308	4.489					0.002	0.036			4.22E6	14.733
EFFLUENT SEWER $10^3m^3/sd$	4.740		2.055								1.140						2.59E6	8.574
SLUDGE SEWER $10^3m^3/sd$										0.060		0.009					2.52E4	0.069
TAILINGS LINE $10^3m^3/sd$																	8.61E7	296.8
DRAINAGE DITCH $10^3m^3/sd$									0.653								3.34E6	10.878
SOLIDS t/sd		27.28														1.662	2.88E7	180358
OTHER SOLIDS t/sd																	3.02E5	944.1
OTHER LIQUIDS $10^3m^3/sd$					0.034												1.51E5	0.547


TO EXTRACTION
TO PLANT
RECYCLE POND
MINE RECLAMATI

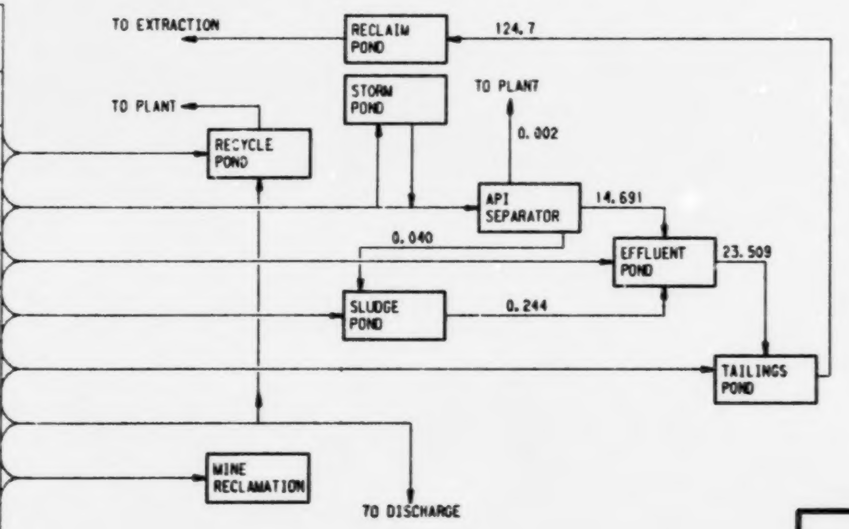
* NOT QUANTIFIED

+ UNITS FOR TOTAL ANNUAL FLOW: ATMOSPHERIC EMISSIONS m^3/yr
LIQUID STREAMS m^3/yr
SOLIDS t/yr


OFFSITES
ATMOSPHERE
38
49
ENT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
PITCH STORAGE
SULPHUR BLOCK
SOLID WASTE
37
39
40
41
42
43
44
45
46
47
48
50
TO RECYCLE POND
TO TREATMENT
TO EFFLUENT POND
TO SLUDGE POND
TO TAILINGS POND
TO DISCHARGE
TO MINE RECLAMATION
TO OFFSITE TREATMENT & DISPOSAL

48	49	50	TOTAL * ANNUAL FLOW	TOTAL FLOW PER SD
	0.018		2.21E10	72.50
			1.84E5	0.609
0.036			4.22E6	14.733
			2.59E6	8.574
			2.52E4	0.069
			8.61E7	296.8
			3.34E6	10.878
		1.662	2.88E7	180358
			3.02E5	944.1
			1.51E5	0.547

TOTAL ANNUAL FLOW ATMOSPHERIC EMISSIONS m³/yr
LIQUID STREAMS m³/yr
SOLIDS t/yr


TO EXTRACTION
RECLAIM POND
124.7
STORM POND
TO PLANT
TO PLANT
0.002
RECYCLE POND
API SEPARATOR
14.691
0.040
EFFLUENT POND
23.509
SLUDGE POND
0.244
TAILINGS POND
MINE RECLAMATION
TO DISCHARGE

◇	WASTE STREAM
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	WET TAILINGS
14	STEAM VENTS
15	WET TAILINGS
16	VENTS
17	WASTEWATER
18	NET PITCH
19	SPENT CATALYST
20	EMISSIONS
21	SULPHUR
22	SWS WASTEWATER
23	CONDENSATE
24	FLUE GAS
25	BLOWDOWN
26	BLOWDOWN
27	FLUE GAS
28	BOTTOM ASH
29	ASH SLUICE BD
30	FLY ASH
31	PRESCRUBBER BD
32	FGD BYPRODUCT
33	FLUE GAS
34	FLUE GAS
35	BLOWDOWN
36	SOFTENER SOLIDS
37	REGENERANT WASTE
38	EMISSIONS
39	TANK BOTTOMS
40	CONDENSATE
41	WASHDOWN
42	INPLANT RUNOFF
43	CLEAN RUNOFF
44	ALUM SLUDGE
45	EFFLUENT
46	DIGESTED SLUDGE
47	PITCH RUNOFF
48	BLOCK RUNOFF
49	INCINERATOR EMIS
50	NONCOMBUSTIBLES

FIGURE 3-5 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 4 HOT WATER EXTRACTION/
H-OIL/PITCH BOILERS

MONENCO CONSULTANTS LIMITED

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AREA	PROCESS	WASTE STREAM	◇	FLOW m^3/sd	TEMP. °C	DENSITY kg/m^3	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3	TKN
MINING	DEWATERING	SHALLOW AQUIFER	3	1448		1000	7.6						295 427					
		BASAL AQUIFER	4	6700		1005	7.4						1440 9648					
		MINE WATER	5	4784		1000	8.3			12 57.4							.28 1.34	
	OVERBURDEN	MUSKEG RUNOFF	8	885		1000	7.3		34 30.1	8 7.08		64.6 57.2	78.7 69.6					.35 .31
		SUBSOIL RUNOFF	9	1844		1000	7.6				30 55.3							
EXTRACTION	HWE/FILTRATION	FILTRATE	15	1.61E5	65	1015	8											
UPGRADING	DILUENT RECOVERY	WASTEWATER	17	2050	88	1000										TRACE	TRACE	
	SOUR WATER STRIPPER	SWS WASTEWATER	21	2808	140	1000	8.1		295 828		204 573					5 14	58 140	
	HYDROGEN PLANT	CONDENSATE	24	2064		1000								TRACE	19 39.2			
		WASTEWATER	25	1186		1000	7.9		4050 4803			1252 1485				5 5.93	144 171	
		STRIPPED WATER	26	103	140	1000	8		295 30.4		204 21						50 5.15	
	UPGRADING STEAM	BLOWDOWN	30	231	174	1000	9.5											
UTILITIES	BOILER PLANT	BLOWDOWN	31	390	174	1000	9.5					400 156						
	COOLING TOWER	BLOWDOWN	35	5510	24	1000	7.5				50 276	50 276					10 55.1	
	WATER T'MENT PLANT	REGENERANT WASTE	37	2120		1000	7						145 307					
OFFSITES	TANKAGE	TANK BOTTOMS	39	34		1100		4.33E5 1.49E4										
	CONDENSATE LEAKAGE	CONDENSATE	40	259		1000						400 104						
	BUILDING DRAINS	WASHDOWN	41	1308		1000	8.1						158 207				.12 .157	1.2 1.57
	SURFACE RUNOFF	INPLANT RUNOFF	42	4489		1000	7.6		511 2292	10 44.9	74.1 333	90 404						7.07 31.7
		CLEAN RUNOFF	43	653		1000	7.6		511 333		74.1 48.4							7.07 4.62
	POTABLE WATER T'MENT	ALUM SLUDGE	44	60		1000		9.70E5 5.82E4										
	SEWAGE TREATMENT	EFFLUENT	45	1140		1000					25 28.5							
		DIGESTED SLUDGE	46	9		1022		9.49E5 8654										
	SULPHUR STORAGE	BLOCK RUNOFF	47	37		1000	6											

MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3	TKN	NO_3	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	SOLVENT	OIL & GREASE	PHENOL	DEA	SO_4	SUL-PHIDES	S_2O_3	PO_4	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
				295 427						7 10.1			467 676									11 15.9				34 49.2				60 98.5	24 34.8		72 104	3 4.34												6 8.69			
				1440 9648									3778 2.53E4									55 369	23.5 157			1060 7102				55 369	30 201		1137 7618					.9 6.03			.5 3.35								
	12 57.4							.28 1.34				6.5 31.1	400 1914						3 14.4								.23 1.1			99.7 477	24.8 119	.31 1.48	66 316	2.87 13.7			.19 .909		.004 .019	.007 .033	.85 4.07		.021 .1	.011 .053		8.25 39.5	.39 1.87		.046 .22
34 30.1	8 7.08		64.6 57.2	78.7 69.6					.35 .31			365 323	10 8.85									.1 .088				1.7 1.5	.06 .053			16.5 14.6	4.5 3.98		4.9 4.34	.5 .442												2.2 1.95			
		30 55.3										6123 1.13E4	150 277													10 18.4				15 27.7	5 9.22		15 27.7																
												4.06E4 6.54E6			1440 2.32E5		205 3.30E4																																
							TRACE	TRACE											TRACE																														
295 [illegible]		204 573					5 14	50 140				10 28.1								12 33.7		33 92.7		150 421		117 329		.1 .201	.36 1.01	9 25.3									.07 .197		8.8 24.7					2.6 7.3			
					TRACE	19 39.2										TRACE																																	
4950 4803			1252 1485				5 5.93	144 171		3 3.56						32.5 38.5				730 866		120 142			3.5 4.15			.4 .474	31 36.8																				
295 30.4		204 21						50 5.15				10 1.03								12 1.24				160 16.5				.1 .01	.4 .041	9 .927									.7 .072		8.8 .906					2.6 .268			
													120 27.7													9 2.08							14 3.23													6 1.39			
			400 156									150 58.5	2500 974																	500 195																35 13.6			
		50 276	50 276					10 55.1				160 882	725 3995						10 55.1			290 1598			TRACE	30 165				170 937	40 220	.24 1.32	95 523	8 44.1	1.84 10.1		.64 3.53		.032 .176	TRACE	4.9 27	.2 1.[illegible]	.044 .242			36 198			
				145 307									6490 1.38E4									3741 7931				481 1020				460 975	138 293		1398 2964	25 53												103 218			
											9.13E4 3145								5.75E5 1.98E4																														
			400 104									1000 259	2500 648						1000 259											150 38.9																35 9.07			
				158 207				.12 .157	1.2 1.57	.046 .06		1000 1308	200 262						1000 1308	3 3.92	270 353	15.1 19.8	32 41.9		1.05 1.37	7.7 10.1	.11 .144			41.8 54.7	9 11.8		23.5 30.7	1.7 2.22			.16 .209									12 15.7			
311 2292	10 44.9	74.1 333	90 404						7.07 31.7	3.17 14.2		1170 5252	350 1571						200 898	.025 .112					1.6 7.18	52 233				15 67.3	5 22.4		15 67.3												52 233				
511 333		74.1 48.4							7.07 4.62	3.17 2.07		660 431	200 131													26 17				15 9.8	5 3.27		15 9.8																
												3.00E4 1800																																					
		25 28.5										25 28.5							25 28.5																														
												5.11E4 466																																					
												200 7.38											TRACE																										

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L	500
LOADING kg/sd	1440

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-9

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION 5 HOT WATER EXTRACTION/TAILINGS
FILTRATION/H-OIL/
PARTIAL OXIDATION OF PITCH
MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY
MINING	SITE PREPARATION	ASH	2	687		400		5000 3.44				5.90E4 40.5					
	OVERBURDEN	MUSKEG	6	2.58E7		840	7.6										
		SUBSOIL	7	1.46E8		1600	7.5								6.30E5 9.20E7	2.07E5 3.03E7	1.62E5 2.37E7
EXTRACTION	FEED SYSTEM	REJECTS	12	8.33E6	82	1484	8.5	1.19E5 9.90E5	1.50E4 1.25E5						8.37E5 6.97E6	8661 7.21E4	2.08E4 1.73E5
	HWE/FILTRATION	DRY TAILINGS	13	1.96E8	65	1600		1.30E5 2.71E7	1.07E4 2.10E6	1520 2.98E5					8.21E5 1.61E8	8500 1.67E6	2.04E4 4.00E6
UPGRADING	HYDROVISBREAKING	SPENT CATALYST	18	9640		4000											
	SULPHUR PLANT	SULPHUR	20	9.75E5		2046		100 97.5				2 1.95					
	HYDROGEN PLANT	SLAG	27	2.14E5		704		9.10E4 1.94E4				8.96E5 1.91E5					
		CHAR	28	1.32E5		734		5000 660				8.58E5 1.13E5					
UTILITIES	WATER T'MENT PLANT	SOFTENER SOLIDS	36	3.58E4		2040		4.00E5 1.43E4									
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	49	1663		4700						5.49E5 913					

AREA	PROCESS	WASTE STREAM	◇	SPENT CA'LYST	TOTAL ORG.	TOTAL INORG.	LIME	$CaCO_3$	$CaSO_4$	METALS	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2
MINING	SITE PREPARATION	ASH	2									1.10E5 75.6					8.50E5 584	2.53E5 174				6.40E4 44		2.40E4 16.5		4.10E4 28.2	1.50E4 10.3		
	OVERBURDEN	MUSKEG	6		9.76E5 2.52E7	2.40E4 6.19E5																							
		SUBSOIL	7																										
EXTRACTION	FEED SYSTEM	REJECTS	12																										
	HWE/FILTRATION	DRY TAILINGS	13																										
UPGRADING	HYDROVISBREAKING	SPENT CATALYST	18	4.32E5 3732													1.84E5 1590					3000 25.9							
	SULPHUR PLANT	SULPHUR	20														15 14.6												
	HYDROGEN PLANT	SLAG	27														9000 1922												
		CHAR	28														1.38E5 1.82E4												
UTILITIES	WATER T'MENT PLANT	SOFTENER SOLIDS	36					6.00E5 2.15E4																					
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	49							4.51E5 750																			

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m³	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
MINING	SITE PREPARATION	EMISSIONS	1	2.22E4	400	101	1.25E6	1.12E5 2489	3.32E5 7379						7.87E5 1.75E4			1.32E4 294		550 12.2				
	FUGITIVE EMISSION	DUST *	10																					
		DIESEL EMISSIONS	11	1.33E4	540	101	1.11E6		560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	330 4.4	1.50E4 200		1.88E4 250	5.46E4 728		5110 68.1	2780 37.1
EXTRACTION	HWE/FILTRATION	STEAM VENTS	14	1.60E6	200	101	7.62E5	7.62E5 1.22E6																
	FROTH TREATMENT	VENTS	16	9670		101	1.47E6	7.72E4 746	798 7.72		2.58E5 2491				7.62E5 7368			1.76E4 170				3.50E5 3386		
UPGRADING	SULPHUR PLANT	EMISSIONS	19	3.19E6	538	105	1.22E6	3.05E4 1.23E5	1.49E5 4.75E5			634 2023	10.2 32.6		1.03E6 3.28E6	211 674								
	OXYGEN PLANT	EMISSIONS	22	2594	20	101	1.19E6		716 1.06		2.34E4 60.6				1.15E6 2975			1.93E4 50.2						
	HYDROGEN PLANT	CO2 VENT	23	2.33E6	25	103	1.55E6	1522 3543	1.22E6 2.83E6	410 954				1580 3678	3.28E5 7.63E5									
	UPGRADING HEATERS	FLUE GAS	24	2.40E7	400	110	1.23E6	9.13E4 2.19E6	2.29E5 5.49E6		4.33E4 1.04E6	30 720	.1 2.4		8.47E5 2.03E7	270 6480		1.52E4 3.65E5						
UTILITIES	NG BOILERS	FLUE GAS	32	2.78E7	177	101	1.18E6	1.22E5 3.40E6	1.51E5 4.20E6		4.32E4 1.20E6				8.51E5 2.37E7	263 7322		1.43E4 3.98E5	5.51 153					
	WASTE HEAT BOILERS	FLUE GAS	33	1.61E7	177	101	1.16E6	1.39E5 2.23E6	1.71E5 2.76E6		7523 1.21E5				8.30E5 1.34E7	18.8 303		1.39E4 2.25E5	6 96.7					
	NG SUPERHEATERS	FLUE GAS	34	1.31E6	177	101	1.10E6	1.32E5 1.73E5	1.63E5 2.14E5		2.33E4 3.06E4				8.44E5 1.11E6	284 373		1.42E4 1.86E4	5.97 7.83					
OFFSITES	FLARE	EMISSIONS	38	8.62E4	1000	101	1.18E6	1.43E5 1.23E4	1.82E5 1.57E4			54 4.66	.7 .06		8.36E5 7.21E4			1.44E4 1239						
	SOLID WASTE	INCINERATOR EMIS	48	1.78E4	650	103	1.23E6	1.22E5 2164	3.06E5 5444			122 2.16	1.5 .027		7.99E5 1.42E4	1105 19.6				123 2.19				

* NOT CHARACTERIZED

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS NOTED OTHERWISE

Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
		6.40E4 44		2.40E4 16.3		4.10E4 28.2	1.50E4 10.3			8.00E4 55				2.10E4 14.4			3.20E5 220	8000 5.5		
		3000 25.9									5.60E4 484			4.60E4 397					1.87E5 1616	
														1.00E6 9.75E5						
											2000 427								2000 427	
											2000 264								2000 264	

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E6

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

DATA PRESENTATION: GASES

PARAMETER	CO_2
CONCENTRATION mg/m^3	4000
LOADING kg/sd	1.42E6

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

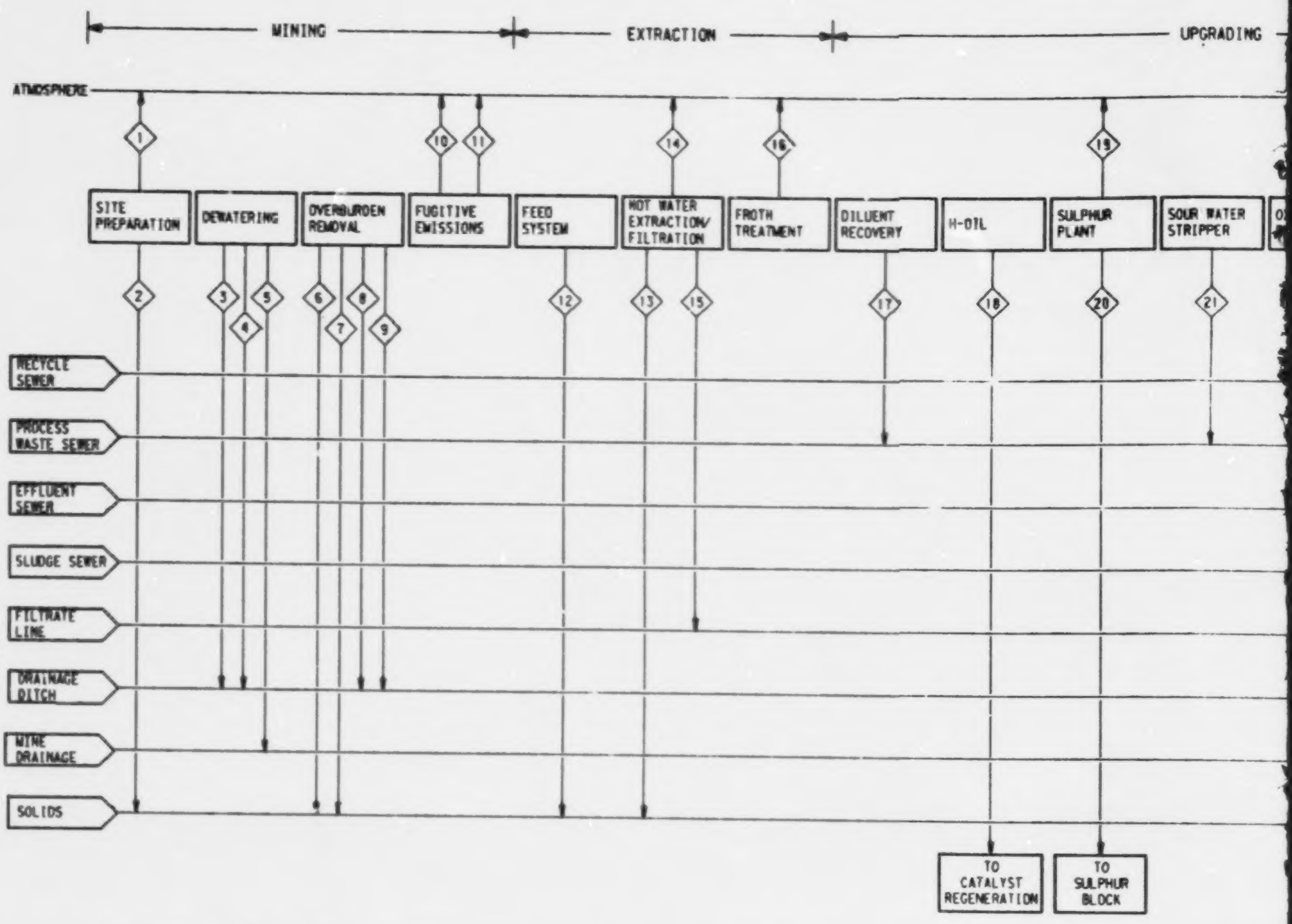
MATRIX 3-10

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

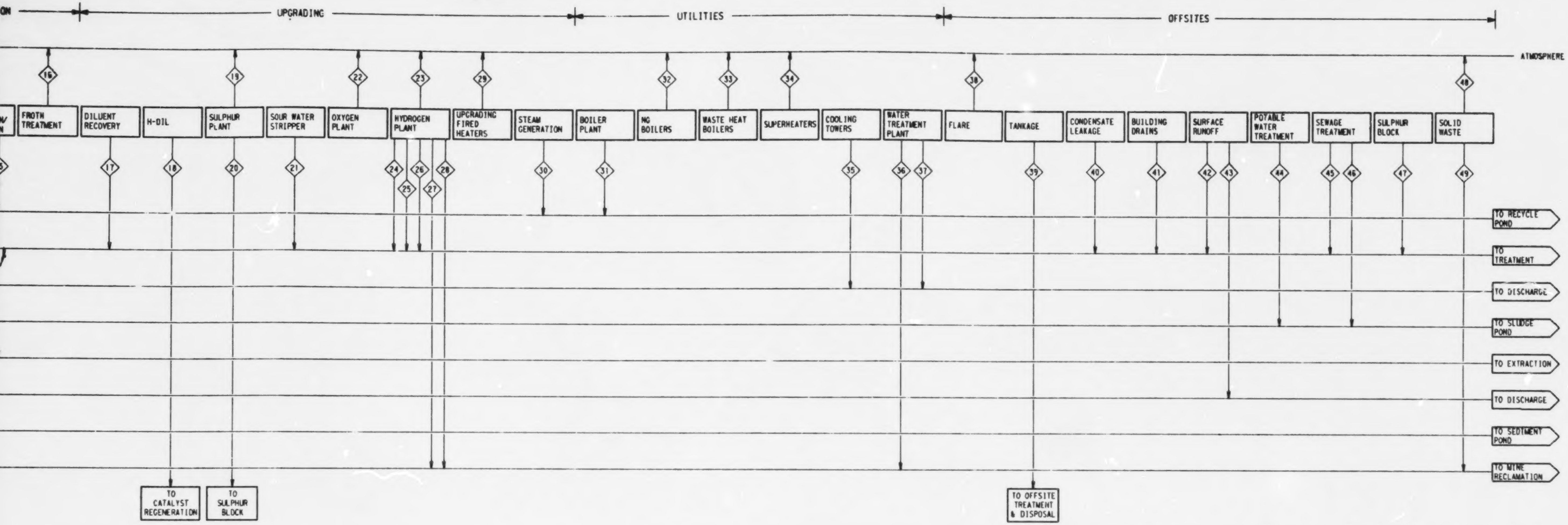
OPTION 5 HOT WATER EXTRACTION/TAILINGS
FILTRATION/H-OIL/
PARTIAL OXIDATION OF PITCH

MONENCO CONSULTANTS LIMITED


MINING
EXTRACTION
UPGRADING
ATMOSPHERE
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
HOT WATER EXTRACTION/ FILTRATION
FROTH TREATMENT
DILUENT RECOVERY
H-OIL
SULPHUR PLANT
SOUR WATER STRIPPER
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
FILTRATE LINE
DRAINAGE DITCH
MINE DRAINAGE
SOLIDS
TO CATALYST REGENERATION
TO SULPHUR BLOCK

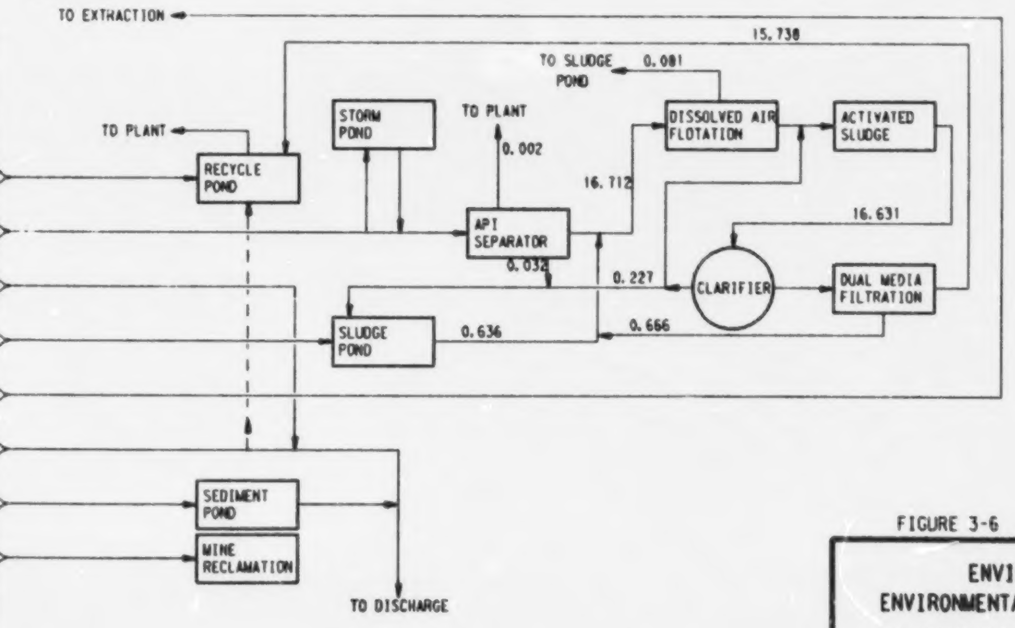
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
ATMOSPHERIC EMISSIONS $10^6 m^3$/sd	0.022									✱	0.013			1.601		0.010			3.192			0.003	2.328				
RECYCLE SEWER $10^3 m^3$/sd																											
PROCESS WASTE SEWER $10^3 m^3$/sd																	2.050				2.808			2.064	1.186	0.103	
EFFLUENT SEWER $10^3 m^3$/sd																											
SLUDGE SEWER $10^3 m^3$/sd																											
FILTRATE LINE $10^3 m^3$/sd															161												
DRAINAGE DITCH $10^3 m^3$/sd			1.448	6.700				0.885	1.844																		
MINE DRAINAGE $10^3 m^3$/sd					4.784																						
SOLIDS t/sd		0.687				25800	146800					8329	196100														213
OTHER SOLIDS t/sd																		8.64		975							
OTHER LIQUIDS $10^3 m^3$/sd																											

✱ NOT QUANTIFIED


ON
UPGRADING
UTILITIES
OFFSITES
ATMOSPHERE
16
19
22
23
29
32
33
34
38
48
FROTH TREATMENT
DILUENT RECOVERY
H-OIL
SULPHUR PLANT
SOUR WATER STRIPPER
OXYGEN PLANT
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
BOILER PLANT
NG BOILERS
WASTE HEAT BOILERS
SUPERHEATERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
SULPHUR BLOCK
SOLID WASTE
17
18
20
21
24
25
26
27
28
30
31
35
36
37
39
40
41
42
43
44
45
46
47
49
TO RECYCLE POND
TO TREATMENT
TO DISCHARGE
TO SLUDGE POND
TO EXTRACTION
TO DISCHARGE
TO SEDIMENT POND
TO MINE RECLAMATION
TO CATALYST REGENERATION
TO SULPHUR BLOCK
TO OFFSITE TREATMENT & DISPOSAL

14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	TOTAL+ ANNUAL FLOW	TOTAL FLOW PER SD
601		0.010			3.192			0.003	2.328						24.00			27.84	16.12	1.312				0.086										0.018		2.32E10	76.55
																0.231	0.390																			1.98E5	0.621
			2.050				2.808			2.064	1.186	0.103														0.259	1.308	4.489			1.140		0.037			4.51E6	15.444
																					5.510		2.120													2.23E6	7.630
																														0.060		0.009				2.52E4	0.069
	161																																			4.70E7	161
																													0.653							3.48E6	11.530
																																				8.12E5	4.784
													213.6	132								28.09													1.663	8.61E7	376605
				8.64		975																														3.14E5	983.64
																									0.034											1.62E3	0.034

+ UNITS FOR TOTAL ANNUAL FLOW: ATMOSPHERIC EMISSIONS m^3/yr
LIQUID STREAMS m^3/yr
SOLIDS t/yr


TO EXTRACTION
15.738
TO SLUDGE POND
0.081
TO PLANT
TO PLANT
0.002
STORM POND
RECYCLE POND
DISSOLVED AIR FLOTATION
ACTIVATED SLUDGE
16.712
16.631
API SEPARATOR
0.032
0.227
CLARIFIER
DUAL MEDIA FILTRATION
SLUDGE POND
0.636
0.666
SEDIMENT POND
MINE RECLAMATION
TO DISCHARGE

◇	WASTE STREAM
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	DRY TAILINGS
14	STEAM VENTS
15	FILTRATE
16	VENTS
17	WASTEWATER
18	SPENT CATALYST
19	EMISSIONS
20	SULPHUR
21	SWS WASTEWATER
22	EMISSIONS
23	CO2 VENT
24	CONDENSATE
25	WASTEWATER
26	STRIPPED WATER
27	SLAG
28	CHAR
29	FLUE GAS
30	BLOWDOWN
31	BLOWDOWN
32	FLUE GAS
33	FLUE GAS
34	FLUE GAS
35	BLOWDOWN
36	SOFTENER SOLIDS
37	REGENERANT WASTE
38	EMISSIONS
39	TANK BOTTOMS
40	CONDENSATE
41	WASHDOWN
42	INPLANT RUNOFF
43	CLEAN RUNOFF
44	ALUM SLUDGE
45	EFFLUENT
46	DIGESTED SLUDGE
47	BLOCK RUNOFF
48	INCINERATOR EMIS
49	NONCOMBUSTIBLES

FIGURE 3-6 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION 5 HOT WATER EXTRACTION/TAILINGS
FILTRATION/H-OIL/
PARTIAL OXIDATION OF PITCH
MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m^3/sd	TEMP. °C	DENSITY kg/m^3	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3
MINING	DEWATERING	SHALLOW AQUIFER	3	1369		1000	7.6						295 404
		BASAL AQUIFER	4	6700		1005	7.4						1440 9648
		MINE WATER	5	4522		1000	8.3			12 54.3			
	OVERBURDEN	MUSKEG RUNOFF	8	1471		1000	7.3		34 50	8 11.8		64.6 95	78.7 116
		SUBSOIL RUNOFF	9	522		1000	7.6				30 15.7		
EXTRACTION	HOT WATER EXTRACTION	WET TAILINGS	13	2.60E5	65	1232	8.5	6.09E5 1.58E8					
	FROTH TREATMENT	WET TAILINGS	15	1.61E4	75	1079	8	8.31E5 1.34E7					
UPGRADING	DILUENT RECOVERY	WASTEWATER	17	2050	80	1000							
	SOUR WATER STRIPPER	SWS WASTEWATER	20	2808	140	1000	8.1		295 828		204 573		
	HYDROGEN PLANT	CONDENSATE	21	3415		1000							
	UPGRADING STEAM	BLOWDOWN	23	231	174	1000	9.5						
UTILITIES	BOILER PLANT	BLOWDOWN	24	359	174	1000	9.5					400 143	
	COOLING TOWER	BLOWDOWN	31	4800	24	1000	7.5				50 240	50 240	
	WATER T'MENT PLANT	REGENERANT WASTE	33	1950		1000	7						145 283
OFFSITES	TANKAGE	TANK BOTTOMS	35	34		1100		4.38E5 1.49E4					
	CONDENSATE LEAKAGE	CONDENSATE	36	259		1000						400 104	
	BUILDING DRAINS	WASHDOWN	37	1308		1000	8.1						158 207
	SURFACE RUNOFF	INPLANT RUNOFF	38	4489		1000	7.6		511 2292	10 44.9	74.1 333	90 404	
		CLEAN RUNOFF	39	653		1000	7.6		511 333		74.1 48.4		
	POTABLE WATER T'MENT	ALUM SLUDGE	40	60		1000		9.70E5 5.82E4					
	SEWAGE TREATMENT	EFFLUENT	41	1140		1000					25 28.5		
		DIGESTED SLUDGE	42	9		1022		9.49E5 8654					
	SULPHUR STORAGE	BLOCK RUNOFF	43	36		1000	6						

WASTE STREAM	◇	H_2	CO_2	H_2S	NH_3	TKN	NO_3	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	SOLVENT
SHALLOW AQUIFER	3						7 9.58			467 639					
BASAL AQUIFER	4									3778 2.53E4					
MINE WATER	5				.28 1.27				6.5 29.4	400 1809					
MUSKEG RUNOFF	8					.35 .515			365 537	10 14.7					
SUBSOIL RUNOFF	9								6123 3196	150 78.3					
WET TAILINGS	13								6.17E5 1.60E8			6776 1.76E6			
WET TAILINGS	15								2.02E5 3.25E6			2.70E4 4.35E5		1.94E4 3.13E5	
WASTEWATER	17			TRACE	TRACE										
SWS WASTEWATER	20			5 14	50 140				10 28.1						
CONDENSATE	21	TRACE	19 64.9										TRACE		
BLOWDOWN	23									120 27.7					
BLOWDOWN	24								150 53.8	2500 896					
BLOWDOWN	31				10 48				160 768	725 3480					
REGENERANT WASTE	33									6490 1.27E4					
TANK BOTTOMS	35							9.13E4 3145							
CONDENSATE	36								1000 259	2500 648					
WASHDOWN	37				.12 .157	1.2 1.57	.046 .06		1000 1308	200 262					
INPLANT RUNOFF	38					7.07 31.7	3.17 14.2		1170 5252	350 1571					
CLEAN RUNOFF	39					7.07 4.62	3.17 2.07		660 431	200 131					
ALUM SLUDGE	40								3.00E4 1800						
EFFLUENT	41								25 28.5						
DIGESTED SLUDGE	42								5.11E4 466						
BLOCK RUNOFF	43								200 7.17						

WASTE STREAM	◇	OIL & GREASE	PHENOL	DEA	SO_4	SUL-PHIDES	S_2O_3	PO_4	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K
SHALLOW AQUIFER	3				11 15.1				34 46.5				68 93.1	24 32.9		72 98.6	3 4.11
BASAL AQUIFER	4				55 369	23.5 157			1060 7102				55 369	30 201		1137 7618	
MINE WATER	5	3 13.6								.23 1.04			99.7 451	24.8 112	.31 1.4	66 298	2.87 13
MUSKEG RUNOFF	8				.1 .147				1.7 2.5	.06 .088			16.5 24.3	4.5 6.62		4.9 7.21	.5 .736
SUBSOIL RUNOFF	9								10 5.22				15 7.83	5 2.61		15 7.83	
WET TAILINGS	13																
WET TAILINGS	15																
WASTEWATER	17	TRACE															
SWS WASTEWATER	20		12 33.7		33 92.7		150 421		117 329		.1 .281	.36 1.01	9 25.3				
CONDENSATE	21																
BLOWDOWN	23								9 2.08							14 3.23	
BLOWDOWN	24												500 179				
BLOWDOWN	31	10 48			290 1392			TRACE	30 144				170 816	40 192	.24 1.15	95 456	8 38.4
REGENERANT WASTE	33				3741 7295				481 938				460 897	138 269		1398 2726	25 48.8
TANK BOTTOMS	35	5.75E5 1.98E4															
CONDENSATE	36	1000 259											150 38.9				
WASHDOWN	37	1000 1308	3 3.92	270 353	15.1 19.8	32 41.9		1.05 1.37	7.7 10.1	.11 .144			41.8 54.7	9 11.8		23.5 30.7	1.7 2.22
INPLANT RUNOFF	38	200 898	.025 .112					1.6 7.18	52 233				15 67.3	5 22.4		15 67.3	
CLEAN RUNOFF	39								26 17				15 9.8	5 3.27		15 9.8	
ALUM SLUDGE	40																
EFFLUENT	41	25 28.5															
DIGESTED SLUDGE	42																
BLOCK RUNOFF	43						TRACE										

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
34 46.5				68 93.1	24 32.9		72 98.6	3 4.11												6 8.21			
1060 7102				55 369	30 201		1137 7618					.9 6.03			.5 3.35								
	.23 1.04			99.7 451	24.8 112	.31 1.4	66 298	2.87 13			.19 .859		.004 .018	.007 .032	.85 3.84		.021 .095	.011 .05		8.25 37.3	.39 1.76		.046 .208
1.7 2.5	.06 .088			16.5 24.3	4.5 6.62		4.9 7.21	.5 .736												2.2 3.24			
10 5.22				15 7.83	5 2.61		15 7.83																
117 329		.1 .281	.36 1.01	9 25.3									.07 .197		8.8 24.7					2.6 7.3			
9 2.08							14 3.23													6 1.39			
				500 179																35 12.6			
30 144				170 816	40 192	.24 1.15	95 456	8 38.4	1.84 8.83		.64 3.07		.032 .154	TRACE	4.9 23.5	.2 .96	.044 .211			36 173			
481 938				460 897	138 269		1398 2726	25 48.8												103 201			
				150 38.9																35 9.07			
7.7 10.1	.11 .144			41.8 54.7	9 11.8		23.5 30.7	1.7 2.22			.16 .209									12 15.7			
52 233				15 67.3	5 22.4		15 67.3												52 233				
26 17				15 9.8	5 3.27		15 9.8																

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L	500
LOADING kg/sd	1440

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-11

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 6 HOT WATER EXTRACTION/CANMET/
PITCH BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

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AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CL
MINING	SITE PREPARATION	ASH	2	650		400		5000 3.25				5.90E4 38.3					
	OVERBURDEN	MUSKEG	6	2.44E7		840	7.6										
		SUBSOIL	7	1.38E8		1600	7.5								6.30E5 8.70E7	2.07E5 2.86E7	1. 2.2
EXTRACTION	FEED SYSTEM	REJECTS	12	7.88E6	82	1484	8.5	1.19E5 9.36E5	1.50E4 1.18E5						8.37E5 6.59E6	8661 6.82E4	2. 1.
UPGRADING	SULPHUR PLANT	SULPHUR	19	8.50E5		2046		100 85				2 1.7					
UTILITIES	PITCH BOILERS	SPENT BED SOLIDS	26	3.59E5	400	1800											
		FLY ASH	27	1.51E5	430	2100	8.5										
	WATER T'MENT PLANT	SOFTENER SOLIDS	32	2.59E4		2040		4.00E5 1.03E4									
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	45	1663		4700						5.49E5 913					

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m³	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	N
MINING	SITE PREPARATION	EMISSIONS	1	2.10E4	400	101	1.25E6	1.12E5 2353	3.32E5 6978						7.87E5 1.65E4		
	FUGITIVE EMISSION	DUST *	10														
		DIESEL EMISSIONS	11	1.33E4	540	101	1.11E6		560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	3 4.
EXTRACTION	HOT WATER EXTRACTION	STEAM VENTS	14	1.51E6	200	101	7.62E5	7.62E5 1.15E6									
	FROTH TREATMENT	VENTS	16	9145		101	1.47E6	7.72E4 706	798 7.3		2.58E5 2355				7.62E5 6968		
UPGRADING	SULPHUR PLANT	EMISSIONS	18	2.60E6	538	105	1.20E6	3.98E4 1.03E5	9.30E4 2.41E5			634 1646	6.77 17.6		1.06E6 2.76E6	211 549	
	UPGRADING HEATERS	FLUE GAS	22	3.20E7	400	110	1.21E6	2.10E4 6.72E5	2.46E5 7.87E6		2.10E4 6.72E5	25 801	.1 3.2		8.37E5 2.68E7	270 8651	
UTILITIES	PITCH BOILERS	FLUE GAS	25	1.22E7	171	101	1.27E6	5.09E4 6.20E5	2.50E5 3.05E6		4.49E4 5.48E5	605 7374	8 97.5		8.94E5 1.09E7	872 1.06E4	
	NG BOILERS	FLUE GAS	28	1.42E7	177	101	1.18E6	1.22E5 1.74E6	1.51E5 2.14E6		4.32E4 6.14E5				8.51E5 1.21E7	263 3737	
	WASTE HEAT BOILERS	FLUE GAS	29	7.36E6	177	101	1.16E6	1.40E5 1.03E6	1.74E5 1.28E6		2805 2.07E4				8.26E5 6.08E6	23.1 170	
	NG SUPERHEATERS	FLUE GAS	30	2.38E6	177	101	1.18E6	1.32E5 3.14E5	1.63E5 3.88E5		2.33E4 5.54E4				8.44E5 2.01E6	284 675	
OFFSITES	FLARE	EMISSIONS	34	8.62E4	1000	101	1.18E6	1.43E5 1.23E4	1.82E5 1.57E4			54 4.66	.7 .06		8.36E5 7.21E4		
	SOLID WASTE	INCINERATOR EMIS	44	1.78E4	650	103	1.23E6	1.22E5 2164	3.06E5 5444			122 2.16	1.5 .027		7.99E5 1.42E4	1105 19.6	

* NOT CHARACTERIZED

WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY	SPENT CA'LYST	TOTAL ORG.	TOTAL INORG.	LIME	$CaCO_3$	$CaSO_4$	METALS	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
5000 3.25				5.90E4 38.3														1.10E5 71.5					8.50E5 552	2.53E5 164				6.40E4 41.6		2.40E4 15.6		4.10E4 26.6	1.50E4 9.75			8.00E4 52				2.10E4 13.6			3.20E5 208	8000 5.2		
											9.76E5 2.38E7	2.40E4 5.86E5																																		
							6.30E5 8.70E7	2.07E5 2.86E7	1.62E5 2.24E7																																					
1.19E5 9.36E5	1.50E4 1.18E5						8.37E5 6.59E6	8661 6.82E4	2.08E4 1.64E5																																					
100 85				2 1.7																			15 12.8																	1.00E6 8.50E5						
													4.92E5 1.77E5		3.98E5 1.43E5			3.28E4 1.18E4						4986 1790				9837 3531		2590 930		1730 621	315 113			1198 430	1605 576	134 48.1					5.20E4 1.87E4		1867 670	
																		3.31E5 4.99E4						3.31E4 4988				9.92E4 1.50E4								8264 1247							5.29E5 7.98E4			
4.00E5 1.03E4														6.00E5 1.55E4																																
				5.49E5 913												4.51E5 750																														

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
1.12E5 2353	3.32E5 6978						7.87E5 1.65E4			1.32E4 278		550 11.6				
	560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	330 4.4	1.50E4 200		1.88E4 250	5.46E4 728		5110 68.1	2780 37.1
7.62E5 1.15E6																
7.72E4 706	798 7.3		2.58E5 2355				7.62E5 6968			1.76E4 161				3.50E5 3203		
3.98E4 1.03E5	9.30E4 2.41E5			634 1646	6.77 17.6		1.06E6 2.76E6	211 549								
2.10E4 6.72E5	2.46E5 7.87E6		2.10E4 6.72E5	25 801	.1 3.2		8.37E5 2.68E7	270 8651		1.52E4 4.87E5						
5.09E4 6.20E5	2.50E5 3.05E6		4.49E4 5.48E5	605 7374	8 97.5		8.94E5 1.09E7	872 1.06E4		1.50E4 1.83E5		125 1524				
1.22E5 1.74E6	1.51E5 2.14E6		4.32E4 6.14E5				8.51E5 1.21E7	263 3737		1.43E4 2.03E5	5.51 78.3					
1.40E5 1.03E6	1.74E5 1.28E6		2805 2.07E4				8.26E5 6.08E6	23.1 170		1.39E4 1.02E5	6 44.2					
1.32E5 3.14E5	1.63E5 3.88E5		2.33E4 5.54E4				8.44E5 2.01E6	284 675		1.42E4 3.37E4	5.97 14.2					
1.43E5 1.23E4	1.82E5 1.57E4			54 4.66	.7 .06		8.36E5 7.21E4			1.44E4 1239						
1.22E5 2164	3.06E5 5444			122 2.16	1.5 .027		7.99E5 1.42E4	1105 19.6				123 2.19				

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS NOTED OTHERWISE

DATA PRESENTATION: GASES

PARAMETER	CO_2
CONCENTRATION mg/m³	4000
LOADING kg/sd	1.42E6

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-12

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 6 HOT WATER EXTRACTION/CANMET/
PITCH BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m^3	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY	SPENT CA'LYST
MINING	SITE PREPARATION	ASH	2	784		400		5000 3.92				5.90E4 46.3						
	OVERBURDEN	MUSKEG	6	2.95E7		840	7.6											
		SUBSOIL	7	1.66E8		1600	7.5								6.30E5 1.05E8	2.07E5 3.44E7	1.62E5 2.69E7	
EXTRACTION	FEED SYSTEM	REJECTS	12	9.50E6	82	1484	8.5	1.19E5 1.13E6	1.50E4 1.43E5						8.37E5 7.95E6	8661 8.23E4	2.08E4 1.98E5	
UPGRADING	GASIFICATION	SLAG	20	2.62E5		726		1.00E5 2.62E4				8.60E5 2.25E5						
	SULPHUR PLANT	SULPHUR	22	1.10E6		2046		100 110				2 2.2						
UTILITIES	WATER T'MENT PLANT	SOFTENER SOLIDS	33	2.52E4		2040		4.00E5 1.01E4										
OFFSITES	SOLIC WASTE	NONCOMBUSTIBLES	46	1663		4700						5.49E5 913						

AREA	PROCESS	WASTE STREAM	◇	TOTAL ORG.	TOTAL INORG.	LIME	$CaCO_3$	$CaSO_4$	METALS	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo
MINING	SITE PREPARATION	ASH	2								1.10E5 86.2					8.50E5 666	2.53E5 198				6.40E4 50.2		2.40E4 18.8		4.10E4 32.1	1.50E4 11.8	
	OVERBURDEN	MUSKEG	6	9.76E5 2.88E7	2.40E4 7.08E5																						
		SUBSOIL	7																								
EXTRACTION	FEED SYSTEM	REJECTS	12																								
UPGRADING	GASIFICATION	SLAG	20													9000 2354											
	SULPHUR PLANT	SULPHUR	22													15 16.5											
UTILITIES	WATER T'MENT PLANT	SOFTENER SOLIDS	33				6.00E5 1.51E4																				
OFFSITES	SOLIC WASTE	NONCOMBUSTIBLES	46						4.51E5 750																		

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m^3/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m^3	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
MINING	SITE PREPARATION	EMISSIONS	1	2.54E4	400	101	1.25E6	1.12E5 2839	3.32E5 8418						7.87E5 2.00E4			1.32E4 336		550 13.9				
	FUGITIVE EMISSION	DUST *	10																					
		DIESEL EMISSIONS	11	1.33E4	540	101	1.11E6		560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	330 4.4	1.50E4 200		1.88E4 250	5.46E4 728		5110 68.1	2780 37.1
EXTRACTION	HOT WATER EXTRACTION	STEAM VENTS	14	1.83E6	200	101	7.62E5	7.62E5 1.39E6																
	FROTH TREATMENT	VENTS	16	1.10E4		101	1.47E6	7.72E4 851	798 8.8		2.58E5 2841				7.62E5 8406			1.76E4 194				3.50E5 3863		
UPGRADING	GASIFICATION	CO2 VENT	19	7.08E5	25	103	1.81E6	2367 1676	1.76E6 1.25E6	1.08E4 7646				730 517	3.12E4 2.21E4									
	SULPHUR PLANT	EMISSIONS	21	3.91E6	538	105	1.26E6	3.60E4 1.41E5	2.60E5 1.02E6			592 2315	10.2 39.9		9.62E5 3.76E6	211 826								
	OXYGEN PLANT	EMISSIONS	24	8312	20	101	1.19E6		716 5.95		2.34E4 194				1.15E6 9534			1.93E4 161						
	UPGRADING HEATERS	FLUE GAS	26	2.64E7	400	110	1.23E6	9.13E4 2.41E6	2.25E5 5.94E6		4.33E4 1.14E6	35 925	.5 13.2		8.50E5 2.24E7	270 7133		1.52E4 4.01E5						
UTILITIES	PG BOILERS	FLUE GAS	29	1.65E7	177	101	1.26E6	9.69E4 1.60E6	3.43E5 5.65E6		3.89E4 6.42E5				7.70E5 1.27E7	298 4911		1.47E4 2.42E5						
	WASTE HEAT BOILERS	FLUE GAS	30	3.67E7	177	101	1.17E6	1.37E5 5.04E6	1.70E5 6.22E6		1.79E4 6.57E5				8.33E5 3.06E7	14.8 543		1.40E4 5.13E5	6.2 227					
	PG SUPERHEATERS	FLUE GAS	31	3.76E6	177	101	1.27E6	1.04E5 3.92E5	3.68E5 1.38E6		2.08E4 7.83E4				7.59E5 2.85E6	321 1208		1.46E4 5.51E4						
OFFSITES	FLARE	EMISSIONS	35	8.33E4	1000	101	1.17E6	1.45E5 1.21E4	1.76E5 1.47E4			249 20.7	3.2 .267		8.36E5 6.96E4			1.40E4 1169						
	SOLID WASTE	INCINERATOR EMIS	45	1.78E4	650	103	1.23E6	1.22E5 2164	3.06E5 5444			122 2.16	1.5 .027		7.99E5 1.42E4	1105 19.6				123 2.19				

* NOT CHARACTERIZED

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS NOTED OTHERWISE

Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
		6.40E4 50.2		2.40E4 18.8		4.10E4 32.1	1.50E4 11.8			8.00E4 62.7				2.10E4 16.5			3.20E5 251	8000 6.27		
											9000 2354								2.20E4 5755	
														1.00E6 1.10E6						

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg LOADING kg/sd	6.00E5 4.85E8

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

DATA PRESENTATION: GASES

PARAMETER	CO_2
CONCENTRATION mg/m^3 LOADING kg/sd	4000 1.42E6

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

MATRIX 3-14

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 7 HOT WATER EXTRACTION/EUREKA/
GASIFICATION OF PITCH

MONENCO CONSULTANTS LIMITED

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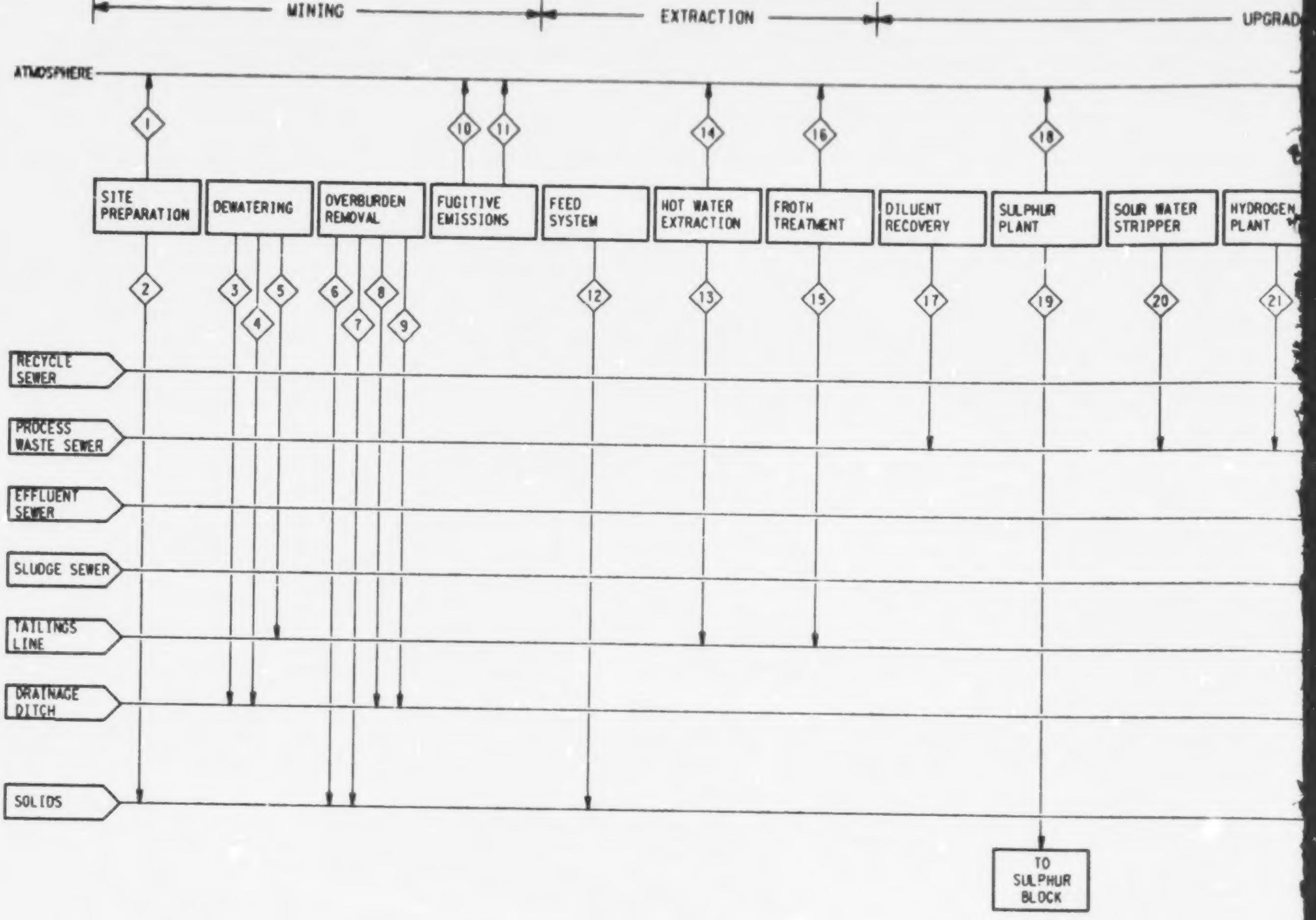
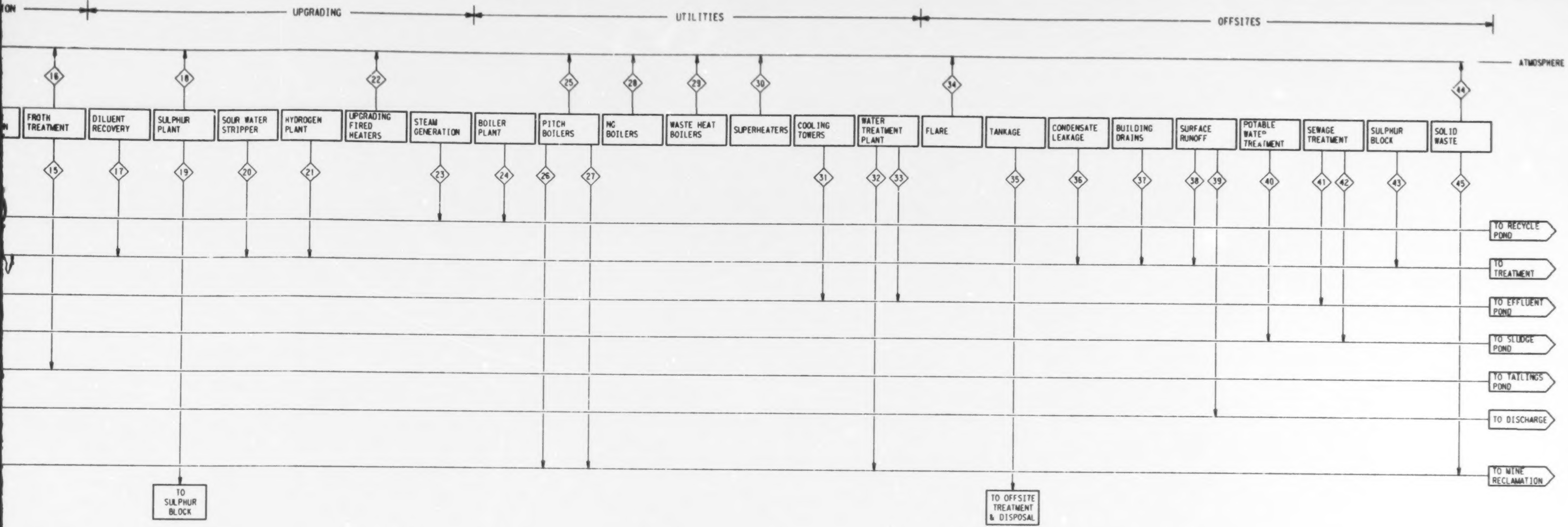

MINING
EXTRACTION
UPGRAD
ATMOSPHERE
1
10
11
14
16
18
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
HOT WATER EXTRACTION
FROTH TREATMENT
DILUENT RECOVERY
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
2
3
4
5
6
7
8
9
12
13
15
17
19
20
21
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
TAILINGS LINE
DRAINAGE DITCH
SOLIDS
TO SULPHUR BLOCK

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	2
ATMOSPHERIC EMISSIONS $10^6 m^3/sd$	0.021									*	0.013			1.515		0.009		2.596				32.04			12.19	
RECYCLE SEWER $10^3 m^3/sd$																							0.231	0.359		
PROCESS WASTE SEWER $10^3 m^3/sd$																	2.050			2.808	3.415					
EFFLUENT SEWER $10^3 m^3/sd$																										
SLUDGE SEWER $10^3 m^3/sd$																										
TAILINGS LINE $10^3 m^3/sd$					4.522								260.1		16.12											
DRAINAGE DITCH $10^3 m^3/sd$			1.369	6.700				1.471	0.522																	
SOLIDS t/sd		0.650				24400	138000					7876														35
OTHER SOLIDS t/sd																			850							
OTHER LIQUIDS $10^3 m^3/sd$																										

* NOT QUANTIFIED

MONENCO CONSULTANTS LIMITED


ON
UPGRADING
UTILITIES
OFFSITES
ATMOSPHERE
FROTH TREATMENT
DILUENT RECOVERY
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
BOILER PLANT
PITCH BOILERS
NG BOILERS
WASTE HEAT BOILERS
SUPERHEATERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
SULPHUR BLOCK
SOLID WASTE
16
18
22
25
28
29
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34
44
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17
19
20
21
23
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31
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41
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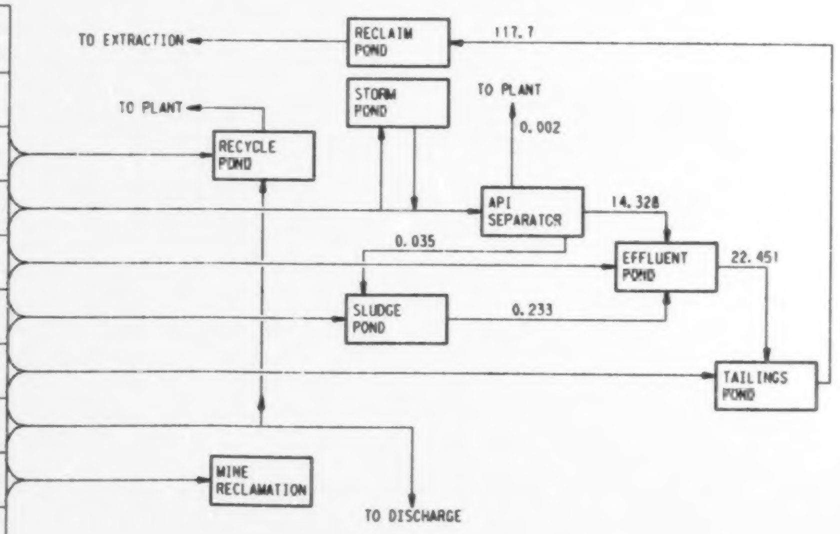
43
45
TO RECYCLE POND
TO TREATMENT
TO EFFLUENT POND
TO SLUDGE POND
TO TAILINGS POND
TO DISCHARGE
TO MINE RECLAMATION
TO SULPHUR BLOCK
TO OFFSITE TREATMENT & DISPOSAL

14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	TOTAL* ANNUAL FLOW	TOTAL FLOW PER SD
15		0.009		2.596				32.04			12.19			14.21	7.364	2.378				0.086										0.018		2.21E10	72.44
									0.231	0.359																						1.79E5	0.590
			2.050			2.808	3.415															0.259	1.308	4.489					0.036			4.11E6	14.365
																	4.800		1.950								1.140					2.39E6	7.890
																										0.060		0.009				2.52E4	0.069
	16.12																															8.14E7	280.7
																									0.653							3.30E6	9.354
												359	150.9					25.85													1.662	2.73E7	170814
					850																											2.71E5	850
																					0.034											1.02E3	0.034

* UNITS FOR TOTAL ANNUAL FLOW
ATMOSPHERIC EMISSIONS m³/yr
LIQUID STREAMS m³/yr
SOLIDS t/yr


TO EXTRACTION
RECLAIM POND
117.7
STORM POND
TO PLANT
0.002
TO PLANT
RECYCLE POND
API SEPARATOR
14.328
0.035
EFFLUENT POND
22.451
SLUDGE POND
0.233
TAILINGS POND
MINE RECLAMATION
TO DISCHARGE

◇	WASTE STREAM
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	WET TAILINGS
14	STEAM VENTS
15	WET TAILINGS
16	VENTS
17	WASTEWATER
18	EMISSIONS
19	SULPHUR
20	SWS WASTEWATER
21	CONDENSATE
22	FLUE GAS
23	BLOWDOWN
24	BLOWDOWN
25	FLUE GAS
26	SPENT BED SOLIDS
27	FLY ASH
28	FLUE GAS
29	FLUE GAS
30	FLUE GAS
31	BLOWDOWN
32	SOFTENER SOLIDS
33	REGENERANT WASTE
34	EMISSIONS
35	TANK BOTTOMS
36	CONDENSATE
37	WASHDOWN
38	INPLANT RUNOFF
39	CLEAN RUNOFF
40	ALUM SLUDGE
41	EFFLUENT
42	DIGESTED SLUDGE
43	BLOCK RUNOFF
44	INCINERATOR EMIS
45	NONCOMBUSTIBLES

FIGURE 3-7 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 6 HOT WATER EXTRACTION/CANMET/
PITCH BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

N00125.PFD F24

WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3	TKN	NO_3	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	SOLVENT	OIL & GREASE	PHENOL	DEA	SO_4	SULPHIDES	S_2O_3	PO_4	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K
MINING	DEWATERING	SHALLOW AQUIFER	3	1651		1000	7.6						295 487						7 11.6			467 771									11 18.2				34 56.1				68 112	24 39.6		72 119	3 4.95
		BASAL AQUIFER	4	6700		1005	7.4						1440 9648									3776 2.53E4									55 369	23.5 157			1060 7102				55 369	30 201		1137 7618	
		MINE WATER	5	5460		1000	8.3			12 65.5							.28 1.53				6.5 35.5	400 2184						3 16.4								.23 1.26			99.7 544	24.8 135	.31 1.69	66 360	2.81 15.7
	OVERBURDEN	MUSKEG RUNOFF	8	1630		1000	7.3		34 55.4	8 13		64.6 105	78.7 128					.35 .571			365 595	10 16.3									.1 .163				1.7 2.77	.06 .098			16.5 26.9	4.5 7.34		4.9 7.99	.5 .815
		SUBSOIL RUNOFF	9	665		1000	7.6				30 20										6123 4072	150 99.8													10 6.65				15 9.98	5 3.33		15 9.98	
EXTRACTION	HOT WATER EXTRACTION	WET TAILINGS	13	3.14E5	65	1232	8.5	6.09E5 1.91E8													6.17E5 1.93E8			6776 2.13E6																			
	FROTH TREATMENT	WET TAILINGS	15	1.95E4	75	1079	8	8.31E5 1.62E7													2.02E5 3.92E6			2.70E4 5.25E5		1.94E4 3.78E5																	
UPGRADING	DILUENT RECOVERY	WASTEWATER	17	2335	88	1000										TRACE	TRACE											TRACE															
	GASIFICATION	WASTEWATER	18	1531		1000	7.9		4050 6201			1252 1917				5 7.66	144 220		3 4.59						32.5 49.8				730 1118		120 184			3.5 5.36			.4 .612	31 47.5					
	SOUR WATER STRIPPER	SWS WASTEWATER	23	8256	140	1000	8.1		295 2436		204 1684					5 41.3	50 413				10 82.6								12 99.1		33 272		150 1238		117 966		.1 .826	.36 2.97	9 74.3				
	HYDROGEN PLANT	CONDENSATE	25	2225		1000								TRACE	13 42.3										TRACE																		
	UPGRADING STEAM	BLOWDOWN	27	344	174	1000	9.5															120 41.3													9 3.1							14 4.82	
UTILITIES	BOILER PLANT	BLOWDOWN	28	350	174	1000	9.5					400 140									150 52.5	2500 875																	500 175				
	COOLING TOWER	BLOWDOWN	32	7090	24	1000	7.5				50 355	50 355					10 70.9				160 1134	725 5140						10 70.9			290 2056			TRACE	30 213				170 1205	40 284	.24 1.7	95 674	8 56.7
	WATER T'MENT PLANT	REGENERANT WASTE	34	1900		1000	7						145 276									6490 1.23E4									3741 7108				481 914				460 874	138 262		1398 2656	25 47.5
OFFSITES	TANKAGE	TANK BOTTOMS	36	39		1100		4.33E5 1.70E4												9.13E4 3588								5.75E5 2.26E4															
	CONDENSATE LEAKAGE	CONDENSATE	37	259		1000						400 104									1000 259	2500 648						1000 259											150 38.9				
	BUILDING DRAINS	WASHDOWN	38	1308		1000	8.1						158 207				.12 .157	1.2 1.57	.046 .06		1000 1308	200 262						1000 1308	3 3.92	270 353	15.1 19.8	32 41.9		1.05 1.37	7.7 10.1	.11 .144			41.8 54.7	9 11.8		23.5 30.7	1.7 2.22
	SURFACE RUNOFF	INPLANT RUNOFF	39	4489		1000	7.6		511 2292	10 44.9	74.1 333	90 404						7.07 31.7	3.17 14.2		1170 5252	350 1571						200 898	.025 .112					1.6 7.18	52 233				15 67.3	5 22.4		15 67.3	
		CLEAN RUNOFF	40	653		1000	7.6		511 333		74.1 48.4							7.07 4.62	3.17 2.07		660 431	200 131													26 17				15 9.8	5 3.27		15 9.8	
	POTABLE WATER T'MENT	ALUM SLUDGE	41	60		1000		9.70E5 5.82E4													3.00E4 1800																						
	SEWAGE TREATMENT	EFFLUENT	42	1140		1000					25 28.5										25 28.5							25 28.5															
		DIGESTED SLUDGE	43	9		1022		9.49E5 8654													5.11E4 466																						
	SULPHUR STORAGE	BLOCK RUNOFF	44	40		1000	6														200 7.99												TRACE										

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

PO₄	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
	34 56.1				68 112	24 39.6		72 119	3 4.95												6 9.91			
	1060 7102				55 369	30 201		1137 7618					.9 6.03			.5 3.35								
		.23 1.26			99.7 544	24.8 135	.31 1.69	66 360	2.87 15.7			.19 1.04		.004 .022	.007 .038	.85 4.64		.021 .115	.011 .06		8.25 45	.39 2.13		.046 .251
	1.7 2.77	.06 .098			16.5 26.9	4.5 7.34		4.9 7.99	.5 .815												2.2 3.59			
	10 6.65				15 9.98	5 3.33		15 9.98																
3.5 .36			.4 .612	31 47.5																				
	117 966		.1 .826	.36 2.97	9 74.3									.07 .578		8.8 72.7					2.6 21.5			
	9 3.1							14 4.82													6 2.06			
					500 175																35 12.2			
RACE	30 213				170 1205	40 284	.24 1.7	95 674	8 56.7	1.84 13		.64 4.54		.032 .227	TRACE	4.9 34.7	.2 1.42	.044 .312			36 255			
	481 914				460 874	138 262		1398 2656	25 47.5												103 196			
					150 38.9																35 9.07			
.05 .37	7.7 10.1	.11 .144			41.8 54.7	9 11.8		23.5 30.7	1.7 2.22			.16 .209									12 15.7			
1.6 .18	52 233				15 67.3	5 22.4		15 67.3												52 233				
	26 17				15 9.8	5 3.27		15 9.8																

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L	500
LOADING kg/ad	1440

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-13

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 7 HOT WATER EXTRACTION/EUREKA/
GASIFICATION OF PITCH

MONENCO CONSULTANTS LIMITED

21

AREA	PROCESS	WASTE STREAM	◇	FLOW m^3/sd	TEMP. °C	DENSITY kg/m^3	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3	TKN
MINING	DEWATERING	SHALLOW AQUIFER	3	1594		1000	7.6						295 470					
		BASAL AQUIFER	4	6700		1005	7.4						1440 9648					
		MINE WATER	5	5460		1000	8.3			12 65.5							.28 1.53	
	OVERBURDEN	MUSKEG RUNOFF	8	907		1000	7.3		34 30.8	8 7.26		64.6 58.6	78.7 71.4					.35 .317
		SUBSOIL RUNOFF	9	2031		1000	7.6				30 60.9							
EXTRACTION	SOLVENT EXTRACTION	WASTEWATER	14	1.06E4	55	1000												
UPGRADING	SOLVENT RECOVERY	WASTEWATER	16	900		1000										TRACE	TRACE	
	SOUR WATER STRIPPER	SWS WASTEWATER	19	4224	140	1000	8.1		295 1246		204 862					5 21.1	50 211	
	HYDROGEN PLANT	CONDENSATE	20	2448		1000								TRACE	19 46.5			
	UPGRADING STEAM	BLOWDOWN	22	236	174	1000	9.5											
UTILITIES	BOILER PLANT	BLOWDOWN	23	518	174	1000	9.5					400 207						
	CO BOILERS	PRESCRUBBER BD	26	1562		1000												
		FGD BYPRODUCT [1]	27	580	45	1020		7.71E5 4.48E6										
	COOLING TOWER	BLOWDOWN	33	1.07E4	24	1000	7.5				50 533	50 533					10 107	
	WATER T'MENT PLANT	REGENERANT WASTE	35	2820		1000	7						145 409					
OFFSITES	TANKAGE	TANK BOTTOMS	37	41		1100		4.33E5 1.78E4										
	CONDENSATE LEAKAGE	CONDENSATE	38	259		1000						400 104						
	BUILDING DRAINS	WASHDOWN	39	1308		1000	8.1						158 207				.12 .157	1.2 1.57
	SURFACE RUNOFF	INPLANT RUNOFF	40	4489		1000	7.6		511 2292	10 44.9	74.1 333	90 404						7.07 31.7
		CLEAN RUNOFF	41	653		1000	7.6		511 333		74.1 48.4							7.07 4.62
	POTABLE WATER T'MENT	ALUM SLUDGE	42	60		1000		9.70E5 5.82E4										
	SEWAGE TREATMENT	EFFLUENT	43	1140		1000					25 28.5							
		DIGESTED SLUDGE	44	9		1022		9.49E5 8654										
	SULPHUR STORAGE	BLOCK RUNOFF	45	34		1000	6											

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[1] ALSO CONTAINS 19.2%wt NH_4HSO_3 AND 7.5%wt $(NH_4)_2SO_3$

MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3	TKN	NO_3	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	SOLVENT	OIL & GREASE	PHENOL	DEA	SO_4	SULPHIDES	S_2O_3	PO_4	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
				295 470						7 11.2			467 744									11 17.5				34 54.2				68 108	24 38.3		72 115	3 4.78												6 9.56			
				1440 9648									3778 2.53E4									55 369	23.5 157			1060 7102				55 369	30 201		1137 7618					.9 6.03			.5 3.35								
	12 65.5							.28 1.53				6.5 35.5	400 2184						4 21.8								.23 1.26			99.7 544	24.8 135	.31 1.69	66 360	2.87 15.7			.19 1.04		.004 .022	.007 .038	.85 4.64		.021 .115	.011 .06		8.25 45	.39 2.13		.046 .251
34 30.8	8 7.26		64.6 58.6	78.7 71.4					.35 .317			365 331	10 9.07									.1 .091				1.7 1.54	.06 .054			16.5 15	4.5 4.08		4.9 4.44	.5 .454												2.2 2			
		30 60.9										6123 1.24E4	150 305													10 20.3				15 30.5	5 10.2		15 30.5																
															TRACE		TRACE																																
							TRACE	TRACE											TRACE																														
295 [illegible]		204 862					5 21.1	50 211				10 42.2								12 50.7		33 139		150 634		117 494		.1 .422	.36 1.52	9 38									.07 .296		8.8 37.2					2.6 11			
					TRACE	19 46.5										TRACE																																	
													120 28.3													9 2.12							14 3.3													6 1.42			
			400 207									150 77.8	2500 1296																	500 259																35 18.1			
												318 500																																					
		50 533	50 533					10 107				160 1704	725 7721						10 107			290 3089			TRACE	30 320				170 1811	40 426	.24 2.56	95 1012	8 85.2	1.84 19.6		.64 6.82		.032 .341	TRACE	4.9 52.2	.2 2.13	.044 .469			36 383			
				145 409									6490 1.83E4									3741 1.05E4				481 1356				460 1297	138 389		1398 3942	25 70.5												103 290			
											9.13E4 3743								5.75E5 2.36E4																														
			400 104									1000 259	2500 648						1000 259											150 38.9																35 9.07			
				158 207				.12 .157	1.2 1.57	.046 .06		1000 1308	200 262						1000 1308	3 3.92	270 353	15.1 19.8	32 41.9		1.05 1.37	7.7 10.1	.11 .144			41.8 54.7	9 11.8		23.5 30.7	1.7 2.22			.16 .209									12 15.7			
511 2292	10 44.9	74.1 333	90 404						7.07 31.7	3.17 14.2		1170 5252	350 1571						200 898	.025 .112					1.6 7.18	52 233				15 67.3	5 22.4		15 67.3												52 233				
511 333		74.1 48.4							7.07 4.62	3.17 2.07		660 431	200 131													26 17				15 9.8	5 3.27		15 9.8																
												3.00E4 1800																																					
		25 28.5										25 28.5							25 28.5																														
												5.11E4 466																																					
												200 6.79											TRACE																									

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L LOADING kg/sd	500 1440

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-15

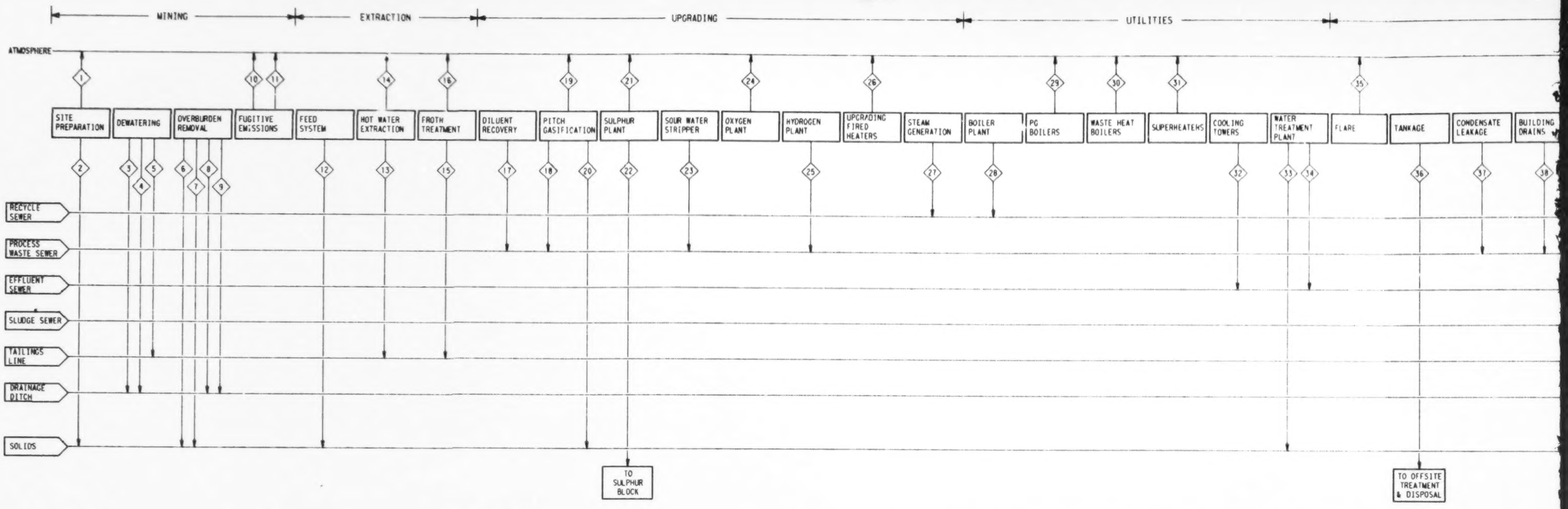
ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 8 SOLVENT EXTRACTION/FLUID COKING/
CO BOILERS/COKE BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

MONENCO CONSULTANTS LIMITED


MINING
EXTRACTION
UPGRADING
UTILITIES
ATMOSPHERE
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
HOT WATER EXTRACTION
FROTH TREATMENT
DILUENT RECOVERY
PITCH GASIFICATION
SULPHUR PLANT
SOUR WATER STRIPPER
OXYGEN PLANT
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
BOILER PLANT
PG BOILERS
WASTE HEAT BOILERS
SUPERHEATERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
TAILINGS LINE
DRAINAGE DITCH
SOLIDS
TO SULPHUR BLOCK
TO OFFSITE TREATMENT & DISPOSAL
1
2
3
4
5
6
7
8
9
10
11
12
13
14
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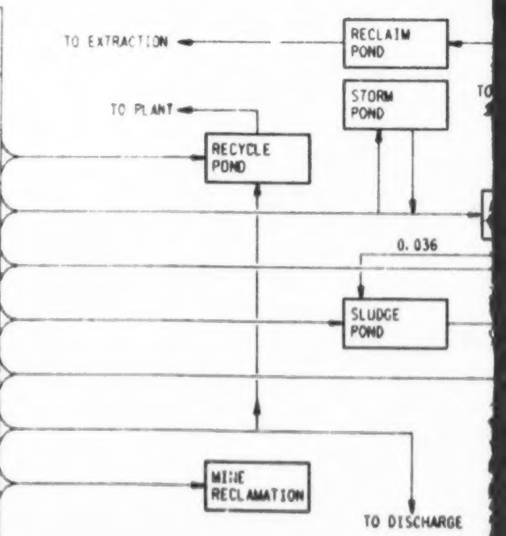
38

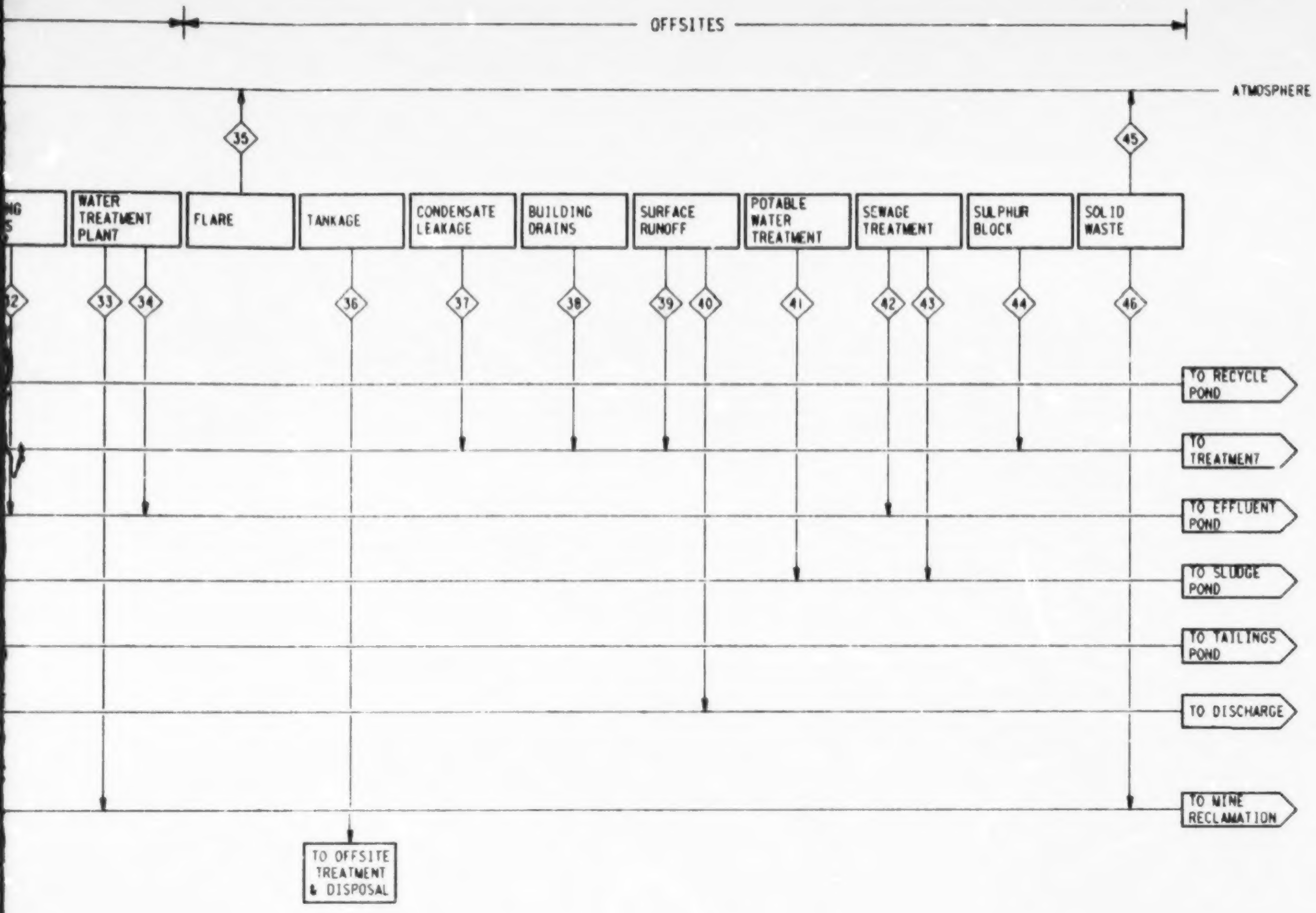
	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱	⑲	⑳	㉑	㉒	㉓
ATMOSPHERIC EMISSIONS $10^6 m^3/sd$	0.025									✱	0.013			1.827		0.011			0.708		3.912		
RECYCLE SEWER $10^3 m^3/sd$																							
PROCESS WASTE SEWER $10^3 m^3/sd$																	2.335	1.531					8.256
EFFLUENT SEWER $10^3 m^3/sd$																							
SLUDGE SEWER $10^3 m^3/sd$																							
TAILINGS LINE $10^3 m^3/sd$					5.460								313.8		19.45								
DRAINAGE DITCH $10^3 m^3/sd$			1.651	6.700				1.630	0.665														
SOLIDS t/sd		0.784				29500	166000					9502								261.6			
OTHER SOLIDS t/sd																						1100	
OTHER LIQUIDS $10^3 m^3/sd$																							

	㉔	㉕	㉖	㉗	㉘	㉙	㉚	㉛	㉜	㉝	㉞	㉟	㊱	㊲	㊳	㊴	㊵	㊶	㊷	㊸	㊹	㊺	㊻	TOTAL⁺ ANNUAL FLOW	TOTAL FLOW PER SD
ATMOSPHERIC EMISSIONS $10^6 m^3/sd$	0.008		26.42			16.48	36.69	3.763				0.083										0.018		2.71E10	89.96
RECYCLE SEWER $10^3 m^3/sd$				0.344	0.350																			2.12E5	0.694
PROCESS WASTE SEWER $10^3 m^3/sd$		2.225												0.259	1.308	4.489					0.040			6.05E6	20.443
EFFLUENT SEWER $10^3 m^3/sd$									7.090		1.900								1.140					3.04E6	10.130
SLUDGE SEWER $10^3 m^3/sd$																		0.060		0.009				2.52E4	0.069
TAILINGS LINE $10^3 m^3/sd$																								9.82E7	338.7
DRAINAGE DITCH $10^3 m^3/sd$																	0.653							3.43E6	11.299
SOLIDS t/sd										25.22													1.662	3.28E7	205291
OTHER SOLIDS t/sd																								3.51E5	1100
OTHER LIQUIDS $10^3 m^3/sd$													0.039											1.17E3	0.039


TO EXTRACTION
RECLAIM POND
STORM POND
TO
TO PLANT
RECYCLE POND
0.036
SLUDGE POND
MINE RECLAMATION
TO DISCHARGE

✱ NOT QUANTIFIED

+ UNITS FOR TOTAL ANNUAL FLOW: ATMOSPHERIC EMISSIONS m^3/yr
LIQUID STREAMS m^3/yr
SOLIDS t/yr

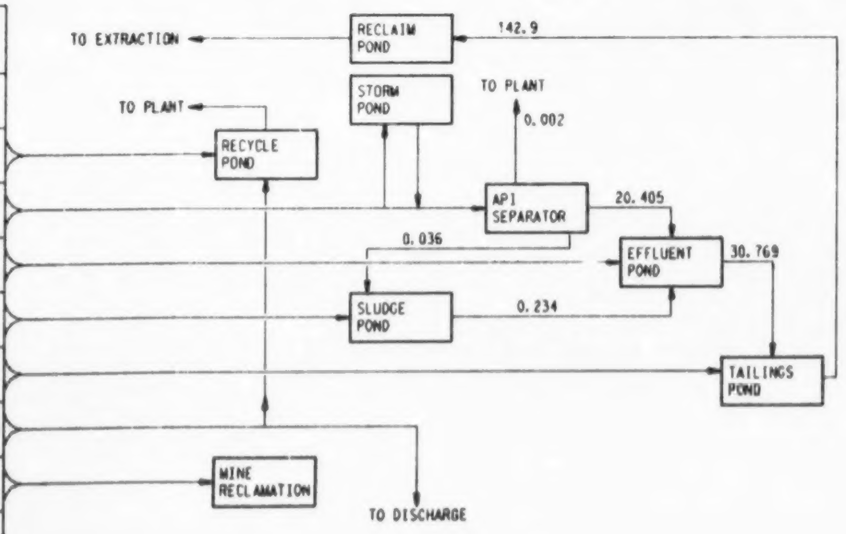


OFFSITES
ATMOSPHERE
NG
S
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
SULPHUR BLOCK
SOLID WASTE
35
45
32
33
34
36
37
38
39
40
41
42
43
44
46
TO RECYCLE POND
TO TREATMENT
TO EFFLUENT POND
TO SLUDGE POND
TO TAILINGS POND
TO DISCHARGE
TO MINE RECLAMATION
TO OFFSITE TREATMENT & DISPOSAL

◇	WASTE STREAM
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	WET TAILINGS
14	STEAM VENTS
15	WET TAILINGS
16	VENTS
17	WASTEWATER
18	WASTEWATER
19	CO2 VENT
20	SLAG
21	EMISSIONS
22	SULPHUR
23	SWS WASTEWATER
24	EMISSIONS
25	CONDENSATE
26	FLUE GAS
27	BLOWDOWN
28	BLOWDOWN
29	FLUE GAS
30	FLUE GAS
31	FLUE GAS
32	BLOWDOWN
33	SOFTENER SOLIDS
34	REGENERANT WASTE
35	EMISSIONS
36	TANK BOTTOMS
37	CONDENSATE
38	WASHDOWN
39	INPLANT RUNOFF
40	CLEAN RUNOFF
41	ALUM SLUDGE
42	EFFLUENT
43	DIGESTED SLUDGE
44	BLOCK RUNOFF
45	INCINERATOR EMIS
46	NONCOMBUSTIBLES

OTAL+ NUAL LOW	TOTAL FLOW PER SD
E10	89.96
12E5	0.694
05E6	20.443
04E6	10.130
52E4	0.069
82E7	338.7
43E6	11.299
28E7	205291
51E5	1100
17E3	0.039

ANNUAL FLOW: ATMOSPHERIC EMISSIONS m^3/yr
LIQUID STREAMS m^3/yr
SOLIDS t/yr



TO EXTRACTION
RECLAIM POND
142.9
STORM POND
TO PLANT
0.002
TO PLANT
RECYCLE POND
API SEPARATOR
20.405
0.036
EFFLUENT POND
30.769
SLUDGE POND
0.234
TAILINGS POND
MINE RECLAMATION
TO DISCHARGE

FIGURE 3-8 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 7 HOT WATER EXTRACTION/EUREKA/
GASIFICATION OF PITCH

MONENCO CONSULTANTS LIMITED

M00126.PFD F24

AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLA
MINING	SITE PREPARATION	ASH	2	757		400		5000 3.78				5.90E4 44.6					
	OVERBURDEN	MUSKEG	6	2.84E7		840	7.6										
		SUBSOIL	7	1.61E8		1600	7.5								6.30E5 1.01E8	2.07E5 3.34E7	1.62E 2.61E
EXTRACTION	FEED SYSTEM	REJECTS	12	8.32E6		1580		5000 4.16E4	1.68E4 1.40E5	TRACE					9.45E5 7.06E6	9702 8.14E4	2.35 1.35
	SOLVENT EXTRACTION	DRY TAILINGS	13	2.23E8	100	1488		1.20E5 2.68E7	4995 1.11E6		1000 2.23E5				8.44E5 1.88E8	8741 1.95E6	2.10 4.6
UPGRADING	SULPHUR PLANT	SULPHUR	18	8.60E5		2046		100 86				2 1.72					
UTILITIES	CO BOILERS	FLY ASH	25	5.48E4	430	2100	8.5										
	COKE BOILERS	SPENT BED SOLIDS	29	1.97E6	400	1800											
		FLY ASH	30	8.11E4	430	2100	8.5										
	WATER T'MENT PLANT	SOFTENER SOLIDS	34	3.74E4		2040		4.00E5 1.49E4									
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	47	1663		4700						5.49E5 913					

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM D

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m³	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NO_x	NH
MINING	SITE PREPARATION	EMISSIONS	1	2.45E4	400	101	1.25E6	1.12E5 2740	3.32E5 8123						7.87E5 1.93E4		
	FUGITIVE EMISSION	DUST *	10														
		DIESEL EMISSIONS	11	1.33E4	540	101	1.11E6		560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	330 4.4
EXTRACTION	SOLVENT EXTRACTION	VENT GAS	15	7.05E5	38	183	1.21E6	3.05E4 2.15E4	277 195		2.72E5 1.92E5				8.87E5 6.26E5		
UPGRADING	SULPHUR PLANT	EMISSIONS	17	2.64E6	538	105	1.20E6	3.98E4 1.05E5	9.30E4 2.45E5			634 1673	6.77 17.9		1.06E6 2.80E6	211 558	
	UPGRADING HEATERS	FLUE GAS	21	2.36E7	400	110	1.24E6	9.13E4 2.16E6	2.59E5 6.11E6		4.21E4 9.94E5	170 4019	3 70.9		6.30E5 1.96E7	270 6303	
UTILITIES	CO BOILERS	FLUE GAS	24	1.76E7	43	101	1.24E6	6.92E4 1.22E6	2.61E5 4.59E6		1.60E4 2.81E5	858 1.51E4	11 194		8.91E5 1.57E7	221 3889	TRACE
	COKE BOILERS	FLUE GAS	28	2.75E7	260	101	1.31E6	1.41E4 3.88E5	3.02E5 8.30E6		4.65E4 1.28E6	1659 4.55E4	21 576		9.24E5 2.54E7	805 2.21E4	
	NG BOILERS	FLUE GAS	31	5.63E6	177	101	1.18E6	1.22E5 6.87E5	1.51E5 8.49E5		4.32E4 2.43E5				8.51E5 4.79E6	263 1400	
	PG SUPERHEATERS	FLUE GAS	32	2.34E6	177	101	1.18E6	1.30E5 3.04E5	1.66E5 3.88E5		2.33E4 5.44E4	104 242	1.31 3.06		8.45E5 1.97E6	301 703	
OFFSITES	FLARE	EMISSIONS	36	1.04E5	1000	[illegible]	1.19E6	1.32E5 1.37E4	1.95E5 2.02E4			600 62.3	8 .831		8.44E5 8.76E4		
	SOLID WASTE	INCINERATOR EMIS	46	1.78E4	650	103	1.23E6	1.22E5 2164	3.06E5 5444			122 2.16	1.5 .027		7.99E5 1.42E4	1105 19.6	

* NOT CHARACTERIZED

WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY	SPENT CA'LYST	TOTAL ORG.	TOTAL INORG.	LIME	$CaCO_3$	$CaSO_4$	METALS	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
5000 3.78				5.90E4 44.6														1.10E5 83.2					8.50E5 643	2.53E5 191				6.40E4 48.4		2.40E4 18.2		4.10E4 31	1.50E4 11.3			8.00E4 60.5				2.10E4 15.9			3.20E5 242	8000 6.05		
											9.76E5 2.77E7	2.40E4 6.82E5																																		
							6.30E5 1.01E8	2.07E5 3.34E7	1.62E5 2.61E7																																					
5000 4.16E4	1.60E4 1.40E5	TRACE					9.45E5 7.86E6	9782 8.14E4	2.35E4 1.95E5																																					
1.20E5 2.60E7	4995 1.11E6		1000 2.23E5				8.44E5 1.88E8	8741 1.95E6	2.10E4 4.60E6																																					
100 86				2 1.72																			15 12.9																	1.00E6 8.60E5						
																		3.31E5 1.81E4						3.31E4 1811				9.92E4 5434								8264 453							5.29E5 2.90E4			
													5.46E5 1.08E6		4.42E5 8.71E5			3099 6106						472 930				985 1941		245 483		164 323	30 59.1			113 223	684 1348	13 25.6					4924 9702		795 1566	
																		3.31E5 2.60E4						3.31E4 2683				9.92E4 8048								8264 671							5.29E5 4.29E4			
4.00E5 1.49E4														6.00E5 2.24E4																																
				5.49E5 913												4.51E5 758																														

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
1.12E5 2740	3.32E5 8123						7.87E5 1.93E4			1.32E4 324		550 13.5				
	560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	330 4.4	1.50E4 200		1.88E4 250	5.46E4 728		5110 68.1	2700 37.1
3.05E4 2.15E4	277 195		2.72E5 1.92E5				8.87E5 6.26E5			1.49E4 1.05E4						
3.98E4 1.05E5	9.30E4 2.45E5			634 1673	6.77 17.9		1.06E6 2.80E6	211 558								
9.13E4 2.16E6	2.59E5 6.11E6		4.21E4 9.94E5	170 4019	3 70.9		8.30E5 1.96E7	270 6383		1.52E4 3.59E5						
6.92E4 1.22E6	2.61E5 4.59E6		1.60E4 2.81E5	858 1.51E4	11 194		8.91E5 1.57E7	221 3889	TRACE	5788 1.02E5		3.1 54.6				
1.41E4 3.88E5	3.02E5 8.30E6		4.65E4 1.28E6	1659 4.55E4	21 576		9.24E5 2.54E7	805 2.21E4		1.55E4 4.26E5		69 1894				
1.22E5 6.87E5	1.51E5 8.49E5		4.32E4 2.43E5				8.51E5 4.79E6	263 1480		1.43E4 8.05E4	5.51 31					
1.30E5 3.04E5	1.66E5 3.88E5		2.33E4 5.44E4	104 242	1.31 3.06		8.45E5 1.97E6	301 703		1.42E4 3.32E4	4.63 10.8					
1.32E5 1.37E4	1.95E5 2.02E4			600 62.3	8 .831		8.44E5 8.76E4			1.42E4 1471						
1.22E5 2164	3.06E5 5444			122 2.16	1.5 .027		7.99E5 1.42E4	1105 19.6				123 2.19				

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

DATA PRESENTATION: GASES

PARAMETER	CO_2
CONCENTRATION mg/m³	4000
LOADING kg/sd	1.42E6

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

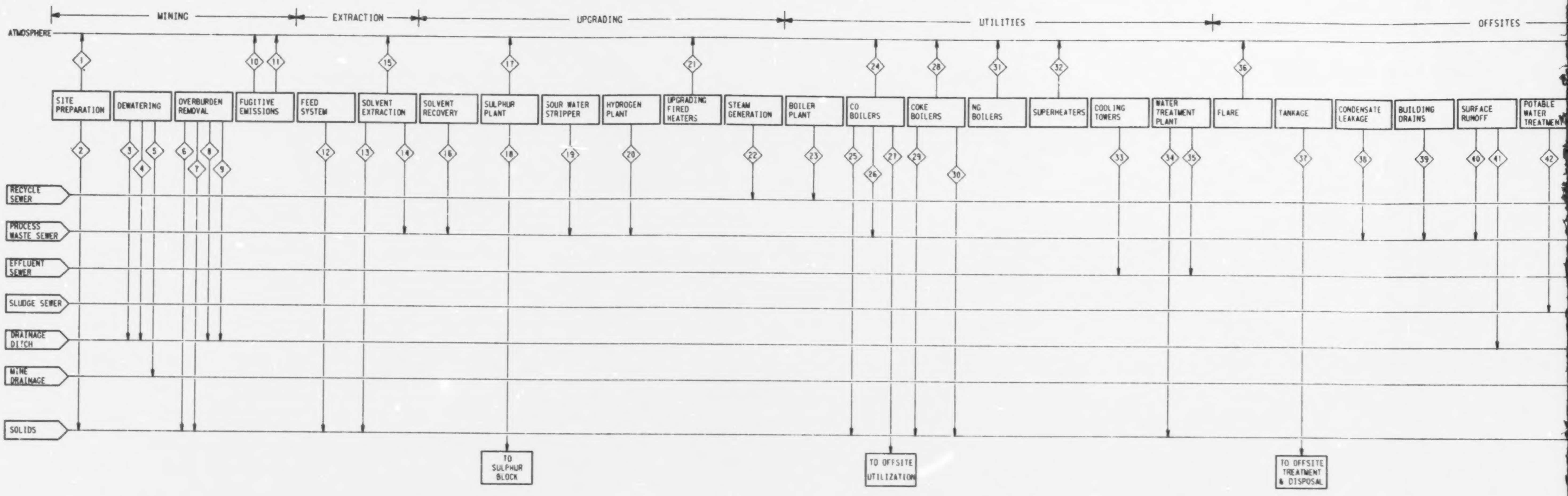
MATRIX 3-16

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 8 SOLVENT EXTRACTION/FLUID COKING/
CO BOILERS/COKE BOILERS (FBC)

MONENCO CONSULTANTS LIMITED


MINING
EXTRACTION
UPGRADING
UTILITIES
OFFSITES
ATMOSPHERE
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
SOLVENT EXTRACTION
SOLVENT RECOVERY
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
BOILER PLANT
CO BOILERS
COKE BOILERS
NG BOILERS
SUPERHEATERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMEN
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
DRAINAGE DITCH
MINE DRAINAGE
SOLIDS
TO SULPHUR BLOCK
TO OFFSITE UTILIZATION
TO OFFSITE TREATMENT & DISPOSAL
1
2
3
4
5
6
7
8
9
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11
12
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17
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19
20
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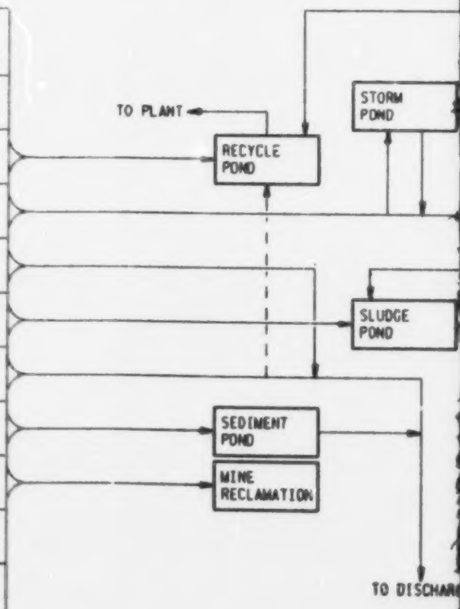
38
39
40
41
42

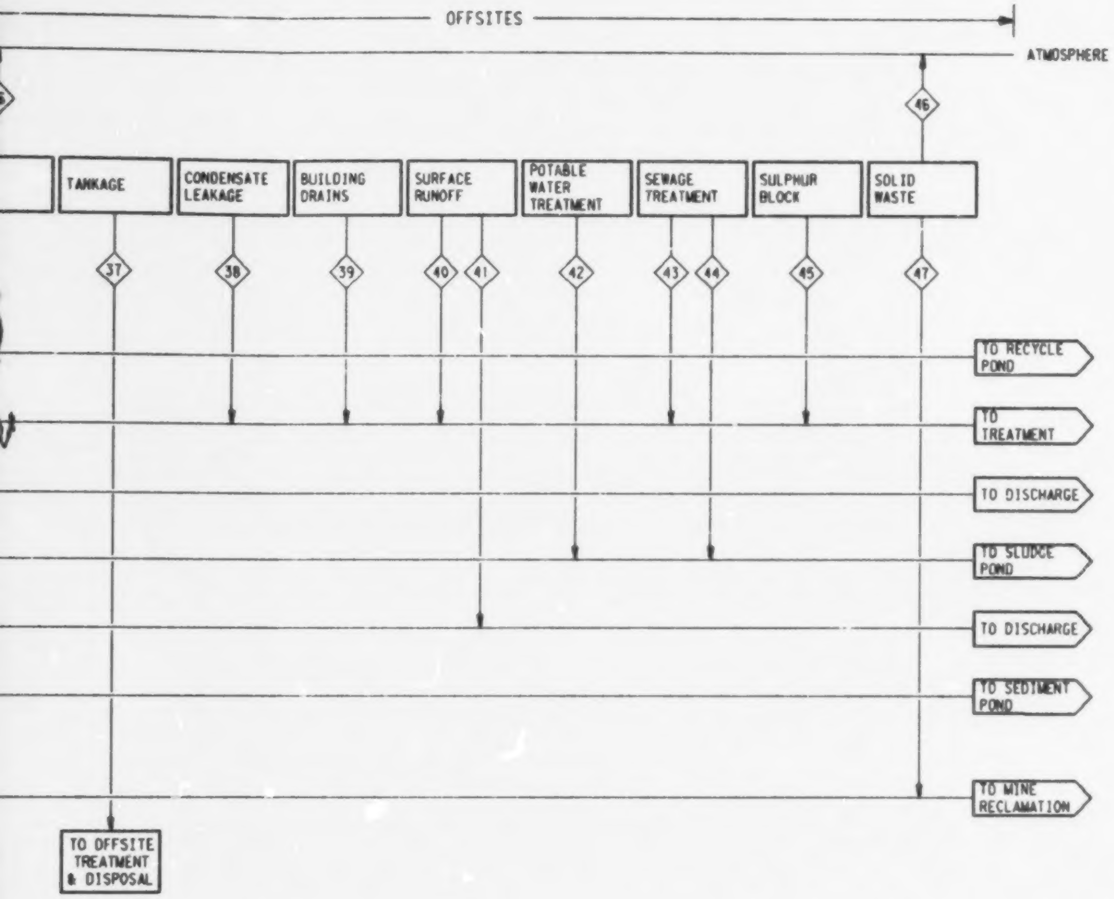
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ATMOSPHERIC EMISSIONS 10^6 m^3/sd	0.024									✱	0.013				0.705		2.640				23.64			17.60
RECYCLE SEWER 10^3 m^3/sd																						0.236	0.518	
PROCESS WASTE SEWER 10^3 m^3/sd														10.56		0.900			4.224	2.448				
EFFLUENT SEWER 10^3 m^3/sd																								
SLUDGE SEWER 10^3 m^3/sd																								
DRAINAGE DITCH 10^3 m^3/sd			1.594	6.700				0.907	2.031															
MINE DRAINAGE 10^3 m^3/sd					5.460																			
SOLIDS t/sd		0.757				28400	161000					8318	223170											
OTHER SOLIDS t/sd																		860						
OTHER LIQUIDS 10^3 m^3/sd																								

	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	TOTAL ANNUAL FLOW +	TOTAL FLOW PER SD
ATMOSPHERIC EMISSIONS 10^6 m^3/sd				27.45			5.627	2.335				0.104										0.018		2.46E10	80.16
RECYCLE SEWER 10^3 m^3/sd																								2.27E5	0.754
PROCESS WASTE SEWER 10^3 m^3/sd		1.562												0.259	1.308	4.489			1.140		0.034			7.89E6	26.92
EFFLUENT SEWER 10^3 m^3/sd									10.65		2.820													4.43E6	13.47
SLUDGE SEWER 10^3 m^3/sd																		0.060		0.009				2.52E4	0.069
DRAINAGE DITCH 10^3 m^3/sd																	0.653							3.55E6	11.89
MINE DRAINAGE 10^3 m^3/sd																								9.27E5	5.460
SOLIDS t/sd	54.79				1970	81.15				37.37													1.662	9.72E7	423034
OTHER SOLIDS t/sd																								2.74E5	860
OTHER LIQUIDS 10^3 m^3/sd			0.580										0.041											1.86E5	0.621


TO PLANT
STORM POND
RECYCLE POND
SLUDGE POND
SEDIMENT POND
MINE RECLAMATION
TO DISCHARG

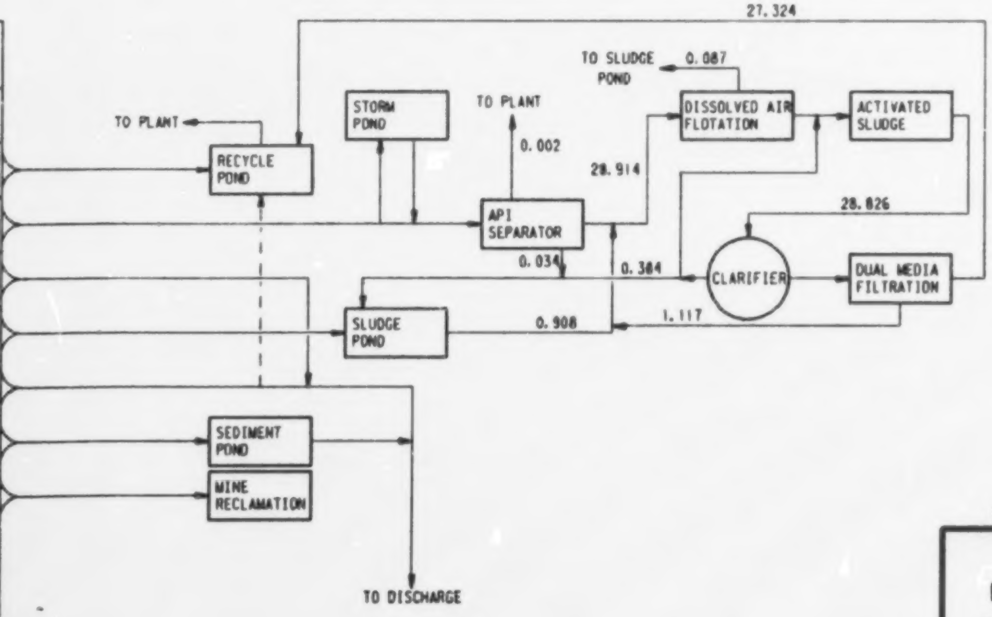
✱ NOT QUANTIFIED

+ UNITS FOR TOTAL ANNUAL FLOW: ATMOSPHERIC EMISSIONS m^3/yr
LIQUID STREAMS m^3/yr
SOLIDS t/yr


OFFSITES
ATMOSPHERE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
SULPHUR BLOCK
SOLID WASTE
46
37
38
39
40
41
42
43
44
45
47
TO RECYCLE POND
TO TREATMENT
TO DISCHARGE
TO SLUDGE POND
TO DISCHARGE
TO SEDIMENT POND
TO MINE RECLAMATION
TO OFFSITE TREATMENT & DISPOSAL

TOTAL ANNUAL FLOW +	TOTAL FLOW PER SD
2.46E10	80.16
2.27E5	0.754
7.89E6	26.92
4.43E6	13.47
2.52E4	0.069
3.55E6	11.89
9.27E5	5.460
9.72E7	423034
2.74E5	860
1.06E5	0.621

ATMOSPHERIC EMISSIONS m³/yr
LIQUID STREAMS m³/yr
SOLIDS t/yr


27.324
TO SLUDGE POND
0.087
TO PLANT
TO PLANT
STORM POND
RECYCLE POND
0.002
28.914
DISSOLVED AIR FLOTATION
ACTIVATED SLUDGE
API SEPARATOR
28.826
0.034
0.384
CLARIFIER
DUAL MEDIA FILTRATION
SLUDGE POND
0.908
1.117
SEDIMENT POND
MINE RECLAMATION
TO DISCHARGE

◇	WASTE STREAM
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	DRY TAILINGS
14	WASTEWATER
15	VENT GAS
16	WASTEWATER
17	EMISSIONS
18	SULPHUR
19	SWS WASTEWATER
20	CONDENSATE
21	FLUE GAS
22	BLOWDOWN
23	BLOWDOWN
24	FLUE GAS
25	FLY ASH
26	PRESCRUBBER BD
27	FGD BYPRODUCT
28	FLUE GAS
29	SPENT BED SOLIDS
30	FLY ASH
31	FLUE GAS
32	FLUE GAS
33	BLOWDOWN
34	SOFTENER SOLIDS
35	REGENERANT WASTE
36	EMISSIONS
37	TANK BOTTOMS
38	CONDENSATE
39	WASHDOWN
40	INPLANT RUNOFF
41	CLEAN RUNOFF
42	ALUM SLUDGE
43	EFFLUENT
44	DIGESTED SLUDGE
45	BLOCK RUNOFF
46	INCINERATOR EMIS
47	NONCOMBUSTIBLES

FIGURE 3-9 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 8 SOLVENT EXTRACTION/FLUID COKING/
CO BOILERS/COKE BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

M08244.PFD F24

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AREA	PROCESS	WASTE STREAM	◇	FLOW m^3/md	TEMP. °C	DENSITY kg/m^3	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3 .	TEM
MINING	DEWATERING	SHALLOW AQUIFER	3	1594		1000	7.6						295 470					
		BASAL AQUIFER	4	6700		1005	7.4						1440 9640					
		MINE WATER	5	5460		1000	8.3			12 65.5							.20 1.53	
	OVERBURDEN	MUSKEG RUNOFF	8	907		1000	7.3		34 30.8	8 7.26		64.6 58.6	78.7 71.4					.35 .317
		SUBSOIL RUNOFF	9	2031		1000	7.6				30 60.9							
EXTRACTION	SOLVENT EXTRACTION	WASTEWATER	14	1.06E4	55	1000												
UPGRADING	SOLVENT RECOVERY	WASTEWATER	16	900		1000										TRACE	TRACE	
	SOUR WATER STRIPPER	SWS WASTEWATER	21	5000	140	1000	8.1		295 1501		204 1038					5 25.4	50 254	
	HYDROGEN PLANT	CONDENSATE	22	2472		1000								TRACE	19 47			
	UPGRADING STEAM	BLOWDOWN	24	240	174	1000	9.5											
UTILITIES	BOILER PLANT	BLOWDOWN	25	567	174	1000	9.5					400 227						
	COOLING TOWER	BLOWDOWN	27	1.58E4	24	1000	7.5				50 790	50 790					10 158	
	WATER T'MENT PLANT	REGENERANT WASTE	29	3000		1000	7						145 447					
OFFSITES	TANKAGE	TANK BOTTOMS	31	41		1100		4.33E5 1.70E4										
	CONDENSATE LEAKAGE	CONDENSATE	32	259		1000						400 104						
	BUILDING DRAINS	WASHDOWN	33	1300		1000	8.1						158 207				.12 .157	1.2 1.57
	SURFACE RUNOFF	INPLANT RUNOFF	34	4489		1000	7.6		511 2292	10 44.9	74.1 333	90 404						7.07 31.7
		CLEAN RUNOFF	35	653		1000	7.6		511 333		74.1 48.4							7.07 4.62
	POTABLE WATER T'MENT	ALUM SLUDGE	36	60		1000		9.70E5 5.82E4										
	SEWAGE TREATMENT	EFFLUENT	37	1140		1000					25 28.5							
		DIGESTED SLUDGE	38	9		1022		9.49E5 8654										
	SULPHUR STORAGE	BLOCK RUNOFF	39	40		1000	6											

WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3	TAN	NO_3	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	SOLVENT	OIL & GREASE	PHENOL	DEA	SO_4	SULPHIDES	S_2O_3	PO_4	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
				295 470						7 11.2			467 744									11 17.5				34 54.2				68 108	24 38.3		72 115	3 4.78												6 9.56			
				1440 9640									3770 2.53E4									55 369	23.5 157			1060 7102				55 369	30 201		1137 7618					.9 6.03			.5 3.35								
	12 65.5							.28 1.53				6.5 35.5	400 2184						3 16.4								.23 1.26			99.7 544	24.8 135	.31 1.69	66 360	2.87 15.7			.19 1.04		.004 .022	.007 .038	.85 4.64		.021 .115	.011 .06		8.25 45	.39 2.13		.046 .251
34 30.8	8 7.26		64.6 58.6	78.7 71.4					.35 .317			365 331	10 9.07									.1 .091				1.7 1.54	.06 .054			16.5 15	4.5 4.08		4.9 4.44	.5 .454												2.2 2			
		30 60.9										6123 1.24E4	150 305													10 20.3				15 30.5	5 10.2		15 30.5																
															TRACE		TRACE																																
							TRACE	TRACE											TRACE																														
295 1501		204 1038					5 25.4	50 254				10 50.9								12 61.1		33 168		150 763		117 595		.1 .509	.36 1.83	9 45.8									.07 .356		8.8 44.8					2.6 13.2			
					TRACE	19 47										TRACE																																	
													120 28.8													9 2.16							14 3.36													6 1.44			
			400 227									150 85	2500 1417																	500 283																35 19.8			
		50 790	50 790					10 158				160 2526	725 1.14E4						10 158			290 4579			TRACE	30 474				170 2684	40 632	.24 3.79	95 1500	8 126	1.84 29.1		.64 10.1		.032 .505	TRACE	4.9 77.4	.2 3.16	.044 .695			36 568			
				145 447									6490 2.00E4									3741 1.15E4				481 1481				460 1417	138 425		1398 4306	25 77												103 317			
											9.13E4 3743								5.75E5 2.36E4																														
			400 104									1000 259	2500 648						1000 259											150 38.9																35 9.07			
				150 207				.12 .157	1.2 1.57	.046 .06		1000 1300	200 262						1000 1300	3 3.92	270 353	15.1 19.8	32 41.9		1.05 1.37	7.7 10.1	.11 .144			41.8 54.7	9 11.8		23.5 30.7	1.7 2.22			.16 .209									12 15.7			
511 2292	10 44.9	74.1 333	90 404						7.07 31.7	3.17 14.2		1170 5252	350 1571						200 898	.025 .112					1.6 7.18	52 233				15 67.3	5 22.4		15 67.3												52 233				
511 333		74.1 48.4							7.07 4.62	3.17 2.07		660 431	200 131													26 17				15 9.8	5 3.27		15 9.8																
												3.00E4 1800																																					
		25 28.5										25 28.5							25 28.5																														
												5.11E4 466																																					
												200 8.08												TRACE																									

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L	500
LOADING kg/sd	1440

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-17

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 9 SOLVENT EXTRACTION/FLEXICOKING/
FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY	SPENT CA'LYST	TOTAL ORG.	TOTAL INORG.	LIME
MINING	SITE PREPARATION	ASH	2	757		400		5000 3.78				5.90E4 44.6									
	OVERBURDEN	MUSKEG	6	2.84E7		840	7.6												9.76E5 2.77E7	2.40E4 6.82E5	
		SUBSOIL	7	1.61E8		1600	7.5								6.30E5 1.01E8	2.07E5 3.34E7	1.62E5 2.61E7				
EXTRACTION	FEED SYSTEM	REJECTS	12	8.32E6		1580		5000 4.16E4	1.68E4 1.40E5	TRACE					9.45E5 7.06E6	9782 8.14E4	2.35E4 1.95E5				
	SOLVENT EXTRACTION	DRY TAILINGS	13	2.23E8	100	1488		1.20E5 2.68E7	4995 1.11E6		1000 2.23E5				8.44E5 1.88E8	8741 1.95E6	2.10E4 4.68E6				
UPGRADING	FLEXICOKING	CHAR	17	6.40E5				7.79E4 4.99E4				1.12E5 7.19E4	7.85E5 5.03E5								
		COKE FINES	18	9.95E4		1100		1.00E5 9954					9.00E5 8.96E4								
	SULPHUR PLANT	SULPHUR	20	1.12E6		2046		100 112				2 2.25									
UTILITIES	WATER T'MENT PLANT	SOFTENER SOLIDS	28	4.09E4		2040		4.00E5 1.63E4													
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	41	1663		4700						5.49E5 913									

AREA	PROCESS	WASTE STREAM	◇	$CaCO_3$	$CaSO_4$	METALS	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo
MINING	SITE PREPARATION	ASH	2					1.10E5 83.2					8.50E5 643	2.53E5 191				6.40E4 48.4		2.40E4 18.2		4.10E4 31	1.50E4 11.3	
	OVERBURDEN	MUSKEG	6																					
		SUBSOIL	7																					
EXTRACTION	FEED SYSTEM	REJECTS	12																					
	SOLVENT EXTRACTION	DRY TAILINGS	13																					
UPGRADING	FLEXICOKING	CHAR	17				1.9 1.22	6512 4168	83 53.1		74 47.4			1520 973	17 10.9	55 35.2	18 11.5	6485 4151	4640 2970	5074 3248		695 445	91 58.2	204 131
		COKE FINES	18																					
	SULPHUR PLANT	SULPHUR	20										15 16.8											
UTILITIES	WATER T'MENT PLANT	SOFTENER SOLIDS	28	6.00E5 2.45E4																				
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	41			4.51E5 750																		

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m³	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
MINING	SITE PREPARATION	EMISSIONS	1	2.45E4	400	101	1.25E6	1.12E5 2740	3.32E5 8123						7.87E5 1.93E4			1.32E4 324		550 13.5				
	FUGITIVE EMISSION	DUST *	10																					
		DIESEL EMISSIONS	11	1.33E4	540	101	1.11E6		560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	330 4.4	1.50E4 200		1.88E4 250	5.46E4 728		5110 68.1	2780 37.1
EXTRACTION	SOLVENT EXTRACTION	VENT GAS	15	7.05E5	38	103	1.21E6	3.05E4 2.15E4	277 195		2.72E5 1.92E5				8.87E5 6.26E5			1.49E4 1.05E4						
UPGRADING	SULPHUR PLANT	EMISSIONS	19	3.58E6	538	105	1.25E6	3.68E4 1.31E5	2.25E5 8.05E5			592 2116	10.2 36.5		9.83E5 3.52E6	211 756								
	UPGRADING HEATERS	FLUE GAS	23	2.40E7	400	110	1.24E6	9.13E4 2.19E6	2.59E5 6.20E6		4.21E4 1.01E6	170 4077	3 71.9		8.30E5 1.99E7	270 6475		1.52E4 3.64E5						
UTILITIES	PG BOILERS	FLUE GAS	26	6.66E7	177	101	1.21E6	1.06E5 7.03E6	2.16E5 1.44E7		3.25E4 2.16E6	666 4.44E4	8.43 561		8.46E5 5.64E7	212 1.41E4		1.07E4 7.11E5	2.58 172					
OFFSITES	FLARE	EMISSIONS	30	1.04E5	1000	101	1.19E6	1.32E5 1.37E4	1.95E5 2.02E4			600 62.3	8 .831		8.44E5 8.76E4			1.42E4 1471						
	SOLID WASTE	INCINERATOR EMIS	40	1.78E4	650	103	1.23E6	1.22E5 2164	3.06E5 5444			122 2.16	1.5 .027		7.99E5 1.42E4	1105 19.6				123 2.19				

* NOT CHARACTERIZED

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.05E8

UNITS AS ABOVE UNLESS NOTED OTHERWISE

Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
		6.40E4 48.4		2.40E4 18.2		4.10E4 31	1.50E4 11.3			8.00E4 60.5				2.10E4 15.9			3.20E5 242	8000 6.05		
55 35.2	18 11.5	6485 4151	4640 2970	5074 3248		695 445	91 58.2	204 131	4824 3088	891 570	1633 1045	174 111	6 3.84	1.51E4 9678				1985 1271	7430 4756	31 19.8
														1.00E6 1.12E6						

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.83E8

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

DATA PRESENTATION: GASES

PARAMETER	CO_2
CONCENTRATION mg/m³	4000
LOADING kg/sd	1.42E6

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

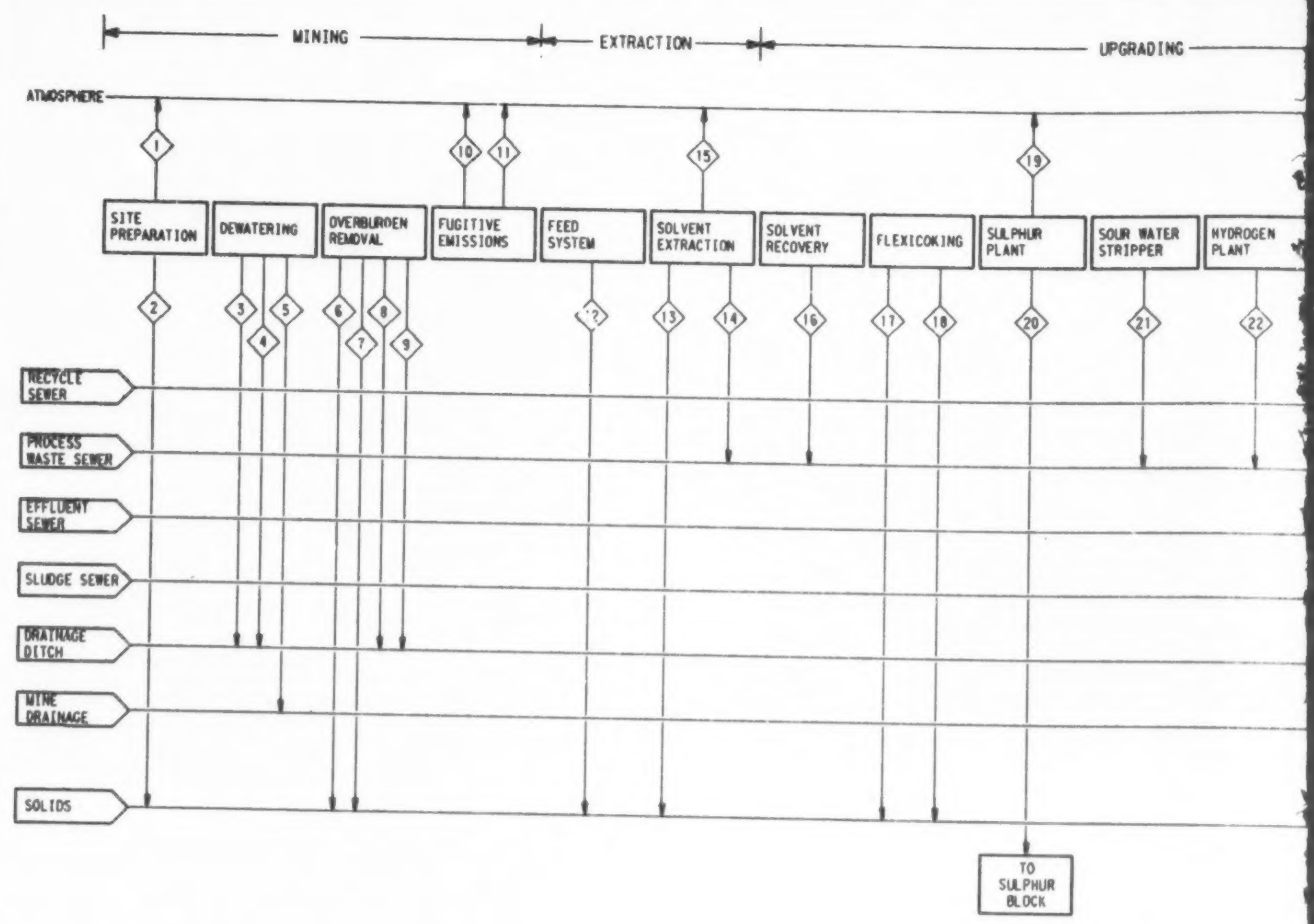
MATRIX 3-18

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

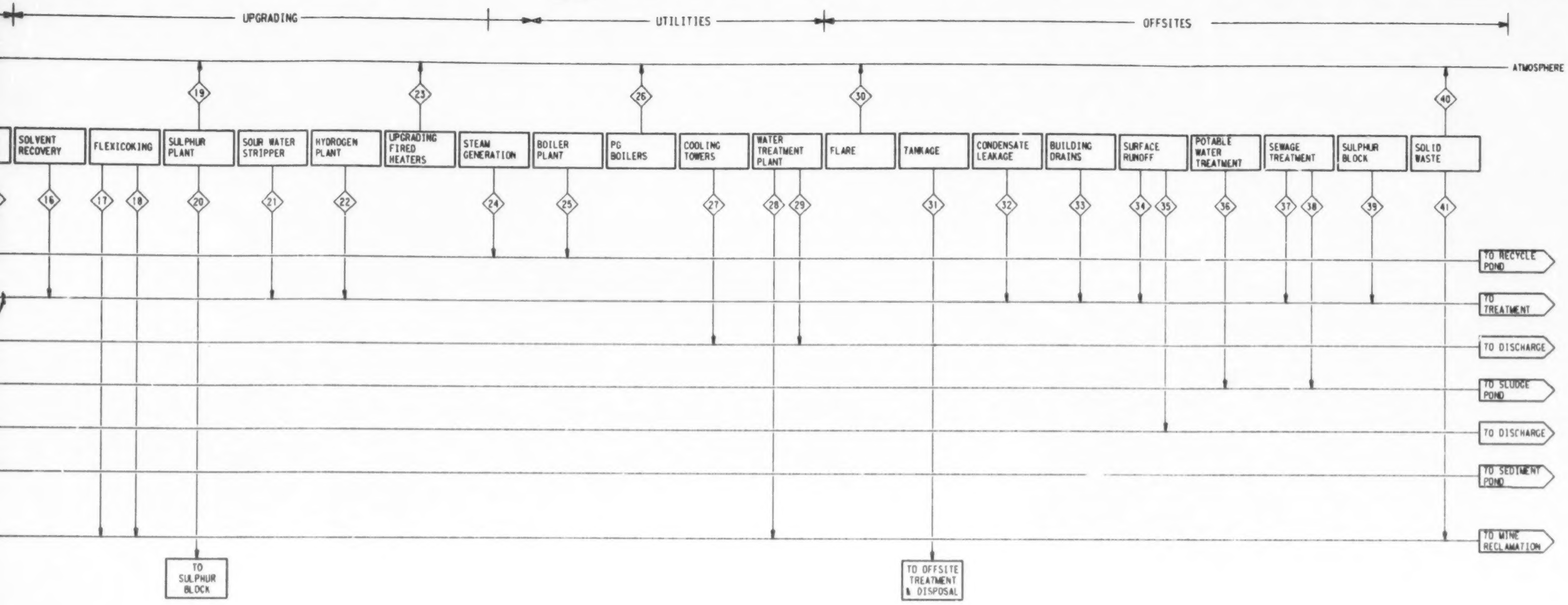
OPTION 9 SOLVENT EXTRACTION/FLEXICOKING/
FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED


MINING
EXTRACTION
UPGRADING
ATMOSPHERE
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
SOLVENT EXTRACTION
SOLVENT RECOVERY
FLEXICOKING
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
DRAINAGE DITCH
MINE DRAINAGE
SOLIDS
TO SULPHUR BLOCK

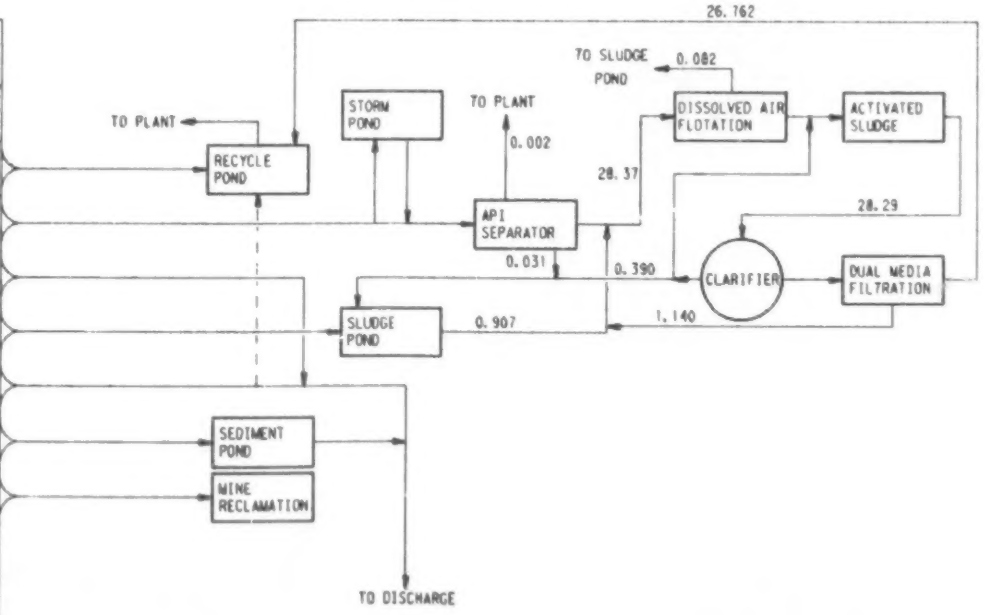
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
ATMOSPHERIC EMISSIONS $10^6m^3/sd$	0.024									*	0.013				0.705				3.576				23.98			66.60
RECYCLE SEWER $10^3m^3/sd$																								0.240	0.567	
PROCESS WASTE SEWER $10^3m^3/sd$														10.56		0.900					5.088	2.472				
EFFLUENT SEWER $10^3m^3/sd$																										
SLUDGE SEWER $10^3m^3/sd$																										
DRAINAGE DITCH $10^3m^3/sd$			1.594	6.700				0.907	2.031																	
MINE DRAINAGE $10^3m^3/sd$					5.460																					
SOLIDS t/sd		0.757				28400	161000					8318	223170				640.1	99.54								
OTHER SOLIDS t/sd																				1123						
OTHER LIQUIDS $10^3m^3/sd$																										

* NOT QUANTIFIED


UPGRADING
UTILITIES
OFFSITES
ATMOSPHERE
SOLVENT RECOVERY
FLEXICOKING
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
BOILER PLANT
PG BOILERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
SULPHUR BLOCK
SOLID WASTE
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
TO RECYCLE POND
TO TREATMENT
TO DISCHARGE
TO SLUDGE POND
TO DISCHARGE
TO SEDIMENT POND
TO MINE RECLAMATION
TO SULPHUR BLOCK
TO OFFSITE TREATMENT & DISPOSAL

	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	TOTAL ANNUAL FLOW +	TOTAL FLOW PER SD
	0.705				3.576				23.98			66.60				0.104										0.018		2.85E10	95.02
										0.240	0.567																	2.42E5	0.807
56		0.900					5.088	2.472										0.259	1.308	4.489			1.140		0.040			7.67E3	26.26
													15.79		3.080													6.17E6	18.87
																						0.060		0.009				2.52E4	0.069
																					0.653							3.55E6	11.89
																												9.27E5	5.460
			640.1	99.54										40.86													1.662	9.69E7	421671
						1123																						3.59E5	1123
																	0.041											1.24E1	0.041

+ UNITS FOR TOTAL ANNUAL FLOW: ATMOSPHERIC EMISSIONS m³/yr
LIQUID STREAMS m³/yr
SOLIDS t/yr


26.762
TO SLUDGE POND
0.082
TO PLANT
STORM POND
TO PLANT
0.002
DISSOLVED AIR FLOTATION
ACTIVATED SLUDGE
RECYCLE POND
28.37
API SEPARATOR
28.29
0.031
0.390
CLARIFIER
DUAL MEDIA FILTRATION
1.140
SLUDGE POND
0.907
SEDIMENT POND
MINE RECLAMATION
TO DISCHARGE

◇	WASTE STREAM
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	DRY TAILINGS
14	WASTEWATER
15	VENT GAS
16	WASTEWATER
17	CHAR
18	COKE FINES
19	EMISSIONS
20	SULPHUR
21	SWS WASTEWATER
22	CONDENSATE
23	FLUE GAS
24	BLOWDOWN
25	BLOWDOWN
26	FLUE GAS
27	BLOWDOWN
28	SOFTENER SOLIDS
29	REGENERANT WASTE
30	EMISSIONS
31	TANK BOTTOMS
32	CONDENSATE
33	WASHDOWN
34	INPLANT RUNOFF
35	CLEAN RUNOFF
36	ALUM SLUDGE
37	EFFLUENT
38	DIGESTED SLUDGE
39	BLOCK RUNOFF
40	INCINERATOR EMIS
41	NONCOMBUSTIBLES

FIGURE 3-10 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 9 SOLVENT EXTRACTION/FLEXICOKING/
FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED

MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m^3/sd	TEMP. °C	DENSITY kg/m^3	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3	TKN	NO_3	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	FATTY ACIDS	OIL & GREASE	PHENOL	DEA	SO_4	SUL-PHIDES	S_2O_3	PO_4	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K
MINING	DEWATERING	SHALLOW AQUIFER	3	1520		1000	7.6						295 451						7 10.7			467 714									11 16.8				34 52				68 104	24 36.7		72 110	3 4.58
		BASAL AQUIFER	4	6700		1005	7.4						1440 9648									3770 2.53E4									55 369	23.5 157			1060 7102				55 369	30 201		1137 7618	
		MINE WATER	5	5050		1000	8.3			12 60.6							.28 1.41				6.5 32.8	400 2020						3 15.2								.23 1.16			99.7 503	24.8 125	.31 1.57	66 333	2.87 14.5
	OVERBURDEN	MUSKEG RUNOFF	8	1453		1000	7.3		34 49.4	8 11.6		64.6 93.9	78.7 114					.35 .509			365 530	10 14.5									.1 .145				1.7 2.47	.06 .087			16.5 24	4.5 6.54		4.9 7.12	.5 .727
		SUBSOIL RUNOFF	9	614		1000	7.6				30 18.4										6123 3759	150 92.1													10 6.14				15 9.21	5 3.07		15 9.21	
EXTRACTION	DIRECT COKING	WASTEWATER	15	1.01E4	49	1000	6.5									2 20.2	32 323										3000 3.03E4		900 9090														
		BLOWDOWN	16	780	174	1000	9.5					400 312									150 117	2500 1950																	500 390				
UPGRADING	SOUR WATER STRIPPER	SWS WASTEWATER	20	1565	140	1000	8.1		295 462		204 319					5 7.83	50 78.3				10 15.7								12 18.8		33 51.6		150 235		117 183		.1 .157	.36 .563	9 14.1				
	HYDROGEN PLANT	CONDENSATE	21	2304		1000								TRACE	19 43.8										TRACE																		
	UPGRADING STEAM	BLOWDOWN	23	140	174	1000	9.5															120 16.8													9 1.26							14 1.96	
UTILITIES	COOLING TOWER	BLOWDOWN	25	1.68E4	24	1000	7.5				50 842	50 842					10 168				160 2694	725 1.22E4						10 168			290 4884			TRACE	30 505				170 2863	40 674	.24 4.04	95 1600	8 135
	WATER T'MENT PLANT	REGENERANT WASTE	27	3403		1000	7						145 493									6490 2.21E4									3741 1.27E4				481 1637				460 1565	138 470		1390 4757	25 85.1
OFFSITES	TANKAGE	TANK BOTTOMS	29	51		1100		4.33E5 2.20E4												9.13E4 4640								5.75E5 2.92E4															
	CONDENSATE LEAKAGE	CONDENSATE	30	259		1000						400 104									1000 259	2500 648						1000 259											150 38.9				
	BUILDING DRAINS	WASHDOWN	31	1046		1000	8.1						158 165				.12 .126	1.2 1.26	.046 .048		1000 1046	200 209						1000 1046	3 3.14	270 282	15.1 15.8	32 33.5		1.05 1.1	7.7 8.05	.11 .115			41.8 43.7	9 9.41		23.5 24.6	1.7 1.78
	SURFACE RUNOFF	INPLANT RUNOFF	32	3265		1000	7.6		511 1667	10 32.7	74.1 242	90 294						7.07 23.1	3.17 10.4		1170 3820	350 1143						200 653	.025 .082					1.6 5.22	52 170				15 49	5 16.3		15 49	
		CLEAN RUNOFF	33	653		1000	7.6		511 333		74.1 48.4							7.07 4.62	3.17 2.07		660 431	200 131													26 17				15 9.8	5 3.27		15 9.8	
	POTABLE WATER T'MENT	ALUM SLUDGE	34	60		1000		9.70E5 5.82E4													3.00E4 1800																						
	SEWAGE TREATMENT	EFFLUENT	35	1140		1000					25 28.5										25 28.5							25 28.5															
		DIGESTED SLUDGE	36	9		1022		9.49E5 8654													5.11E4 466																						
	SULPHUR STORAGE	BLOCK RUNOFF	37	29		1000	6														200 5.74												TRACE										

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
34 52				68 104	24 36.7		72 110	3 4.58												5 9.17			
1060 7102				55 369	30 201		1137 7610					.9 6.03			.5 3.35								
	.23 1.16			99.7 503	24.8 125	.31 1.57	66 333	2.07 14.5			.19 .959		.004 .02	.007 .035	.85 4.29		.021 .106	.011 .056		8.25 41.7	.39 1.97		.046 .232
1.7 2.47	.06 .087			16.5 24	4.5 6.54		4.9 7.12	.5 .727												2.2 3.2			
10 6.14				15 9.21	5 3.07		15 9.21																
				500 390																35 27.3			
117 183		.1 .157	.36 .563	9 14.1									.07 .11		8.8 13.8					2.6 4.07			
9 1.26							14 1.96													6 .84			
30 505				170 2863	40 674	.24 4.04	95 1600	8 135	1.84 31		.64 10.8		.032 .539	TRACE	4.9 82.5	.2 3.37	.044 .741			36 606			
481 1637				460 1565	138 470		1398 4757	25 85.1												103 351			
				150 38.9																35 9.07			
7.7 8.05	.11 .115			41.8 43.7	9 9.41		23.5 24.6	1.7 1.78			.16 .167									12 12.6			
52 170				15 49	5 16.3		15 49												52 170				
26 17				15 9.8	5 3.27		15 9.8																

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L	500
LOADING kg/sd	1440

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

MATRIX 3-19

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 10 DIRECT COKING

MONENCO CONSULTANTS LIMITED

29

AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLA
MINING	SITE PREPARATION	ASH	2	725		400		5000 3.63				5.90E4 42.8					
	OVERBURDEN	MUSKEG	6	2.73E7		840	7.6										
		SUBSOIL	7	1.54E8		1600	7.5								6.30E5 9.71E7	2.07E5 3.19E7	1.62 2.50
EXTRACTION	FEED SYSTEM	REJECTS	12	6.56E6		1484	8.5	1.00E5 6.56E5	2.00E4 1.31E5						8.50E5 5.57E6	8799 5.77E4	2.11 1.38
	DIRECT COKING	SPENT SAND	13	1.90E8		1600		5.00E4 9.48E6							9.22E5 1.75E8		
UPGRADING	SULPHUR PLANT	SULPHUR	19	4.45E5		2046		100 44.5				2 .891					
UTILITIES	WATER T'MENT PLANT	SOFTENER SOLIDS	26	4.51E4		2040		4.00E5 1.81E4									
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	39	1663		4700						5.49E5 913					

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM D

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m³	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH
MINING	SITE PREPARATION	EMISSIONS	1	2.35E4	400	101	1.25E6	1.12E5 2627	3.32E5 7788						7.87E5 1.85E4		
	FUGITIVE EMISSION	DUST X	10														
		DIESEL EMISSIONS	11	1.33E4	540	101	1.11E6		560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	330 4.4
EXTRACTION	DIRECT COKING	FLUE GAS	14	1.43E8	240	101	1.18E6	1.18E5 1.69E7	1.25E5 1.79E7		1.10E5 1.57E7	471 6.76E4			8.25E5 1.18E8	118 1.69E4	
	CALCINATING PLANT	FLUE GAS	17	1.92E6	140	101	1.42E6	6.47E4 1.24E5	7.44E5 1.42E6		3.11E4 5.96E4				5.82E5 1.12E6		
UPGRADING	SULPHUR PLANT	EMISSIONS	18	1.40E6	538	105	1.20E6	3.98E4 5.58E4	9.30E4 1.30E5			634 889	6.77 9.5		1.06E6 1.49E6	211 296	
	UPGRADING HEATERS	FLUE GAS	22	1.98E7	400	110	1.23E6	9.13E4 1.81E6	2.44E5 4.83E6		4.26E4 6.44E5	16 317	.3 5.95		8.38E5 1.66E7	270 5351	
UTILITIES	NG SUPERHEATERS	FLUE GAS	24	1.94E6	177	101	1.18E6	1.32E5 2.56E5	1.63E5 3.17E5		2.33E4 4.52E4				8.44E5 1.64E6	284 551	
OFFSITES	FLARE	EMISSIONS	28	1.04E5	1000	101	1.19E6	1.32E5 1.37E4	1.95E5 2.02E4			600 62.3	8 .831		8.44E5 8.76E4		
	SOLID WASTE	INCINERATOR EMIS	38	1.78E4	650	103	1.23E6	1.22E5 2164	3.06E5 5444			122 2.16	1.5 .027		7.99E5 1.42E4	1105 19.6	

X NOT CHARACTERIZED

MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY	SPENT CA'LYST	TOTAL ORG.	TOTAL INORG.	LIME	$CaCO_3$	$CaSO_4$	METALS	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
5000 3.83				5.90E4 42.8														1.10E5 79.8					8.50E5 617	2.53E5 184				6.40E4 46.4		2.40E4 17.4		4.10E4 29.7	1.50E4 10.9			8.00E4 58				2.10E4 15.2			3.20E5 232	8000 5.8		
											9.76E5 2.66E7	2.40E4 6.55E5																																		
							6.30E5 9.71E7	2.07E5 3.19E7	1.62E5 2.50E7																																					
1.00E5 6.58E5	2.00E4 1.31E5						8.50E5 5.57E6	8799 5.77E4	2.11E4 1.38E5																																					
5.00E4 9.48E6							9.22E5 1.75E8						1.19E4 2.26E6		1.53E4 2.90E6								971 1.84E5																							
100 44.5				2 .891																			15 6.68																	1.00E6 4.45E5						
4.00E5 1.81E4														6.00E5 2.71E4																																
				5.49E5 913												4.51E5 750																														

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
1.12E5 2627	3.32E5 7788						7.87E5 1.85E4			1.32E4 311		550 12.9				
	560 7.46	1.02E4 136	6.66E4 888	7564 101	95.8 1.28		8.91E5 1.19E4	3.75E4 500	330 4.4	1.50E4 200		1.88E4 250	5.46E4 728		5110 68.1	2780 37.1
1.18E5 1.69E7	1.25E5 1.79E7		1.10E5 1.57E7	471 6.76E4			8.25E5 1.18E8	118 1.69E4				115 1.65E4				
6.47E4 .24E5	7.44E5 1.42E6		3.11E4 5.96E4				5.82E5 1.12E6					135 259				
.98E4 5.58E4	9.30E4 1.30E5			634 889	6.77 9.5		1.06E6 1.49E6	211 296								
9.13E4 1.81E6	2.44E5 4.83E6		4.26E4 8.44E5	16 317	.3 5.95		8.38E5 1.66E7	270 5351		1.52E4 3.01E5						
.32E5 2.56E5	1.63E5 3.17E5		2.33E4 4.52E4				8.44E5 1.64E6	284 551		1.42E4 2.75E4	5.97 11.6					
1.32E5 1.37E4	1.95E5 2.02E4			600 62.3	8 .831		8.44E5 8.76E4			1.42E4 1471						
1.22E5 2164	3.06E5 5444			122 2.16	1.5 .027		7.99E5 1.42E4	1105 19.6				123 2.19				

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

DATA PRESENTATION: GASES

PARAMETER	CO_2
CONCENTRATION mg/m^3	4000
LOADING kg/sd	1.42E6

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

MATRIX 3-20

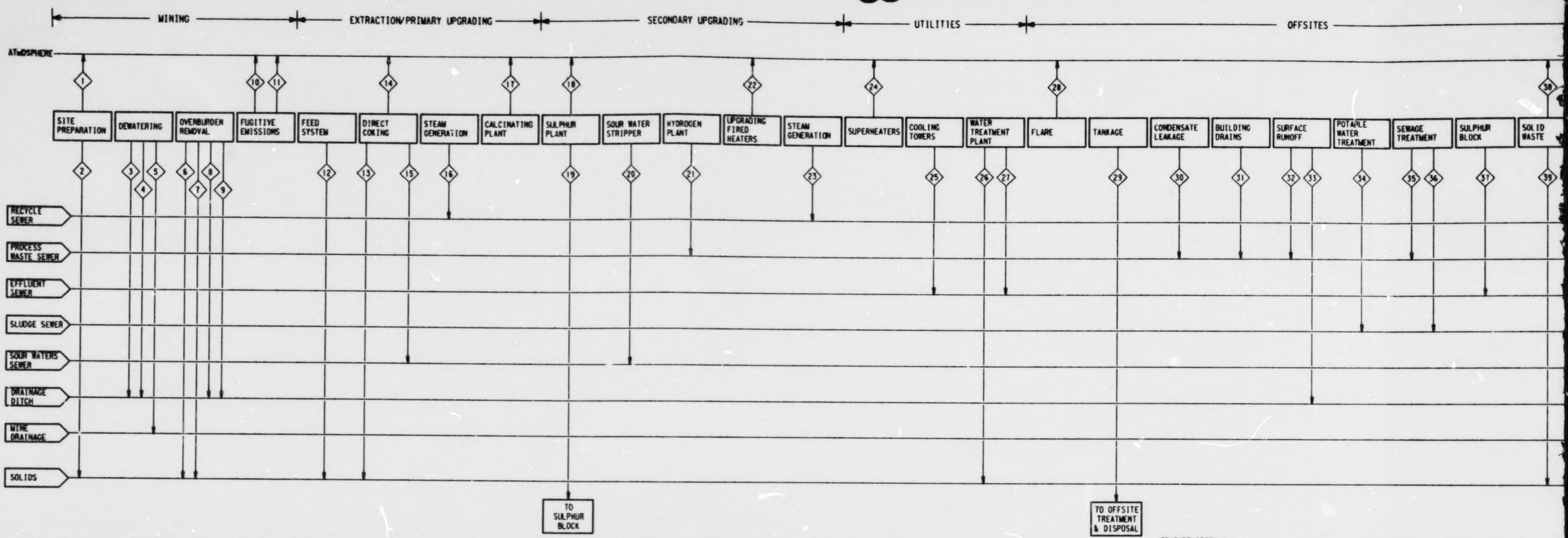
ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 10   DIRECT COKING

MONENCO CONSULTANTS LIMITED

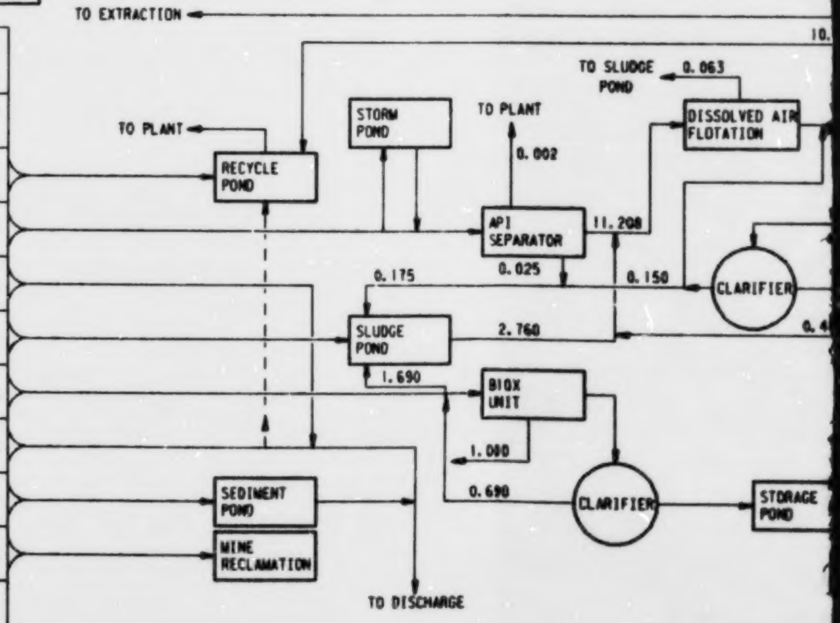
MONENCO CONSULTANTS LIMITED

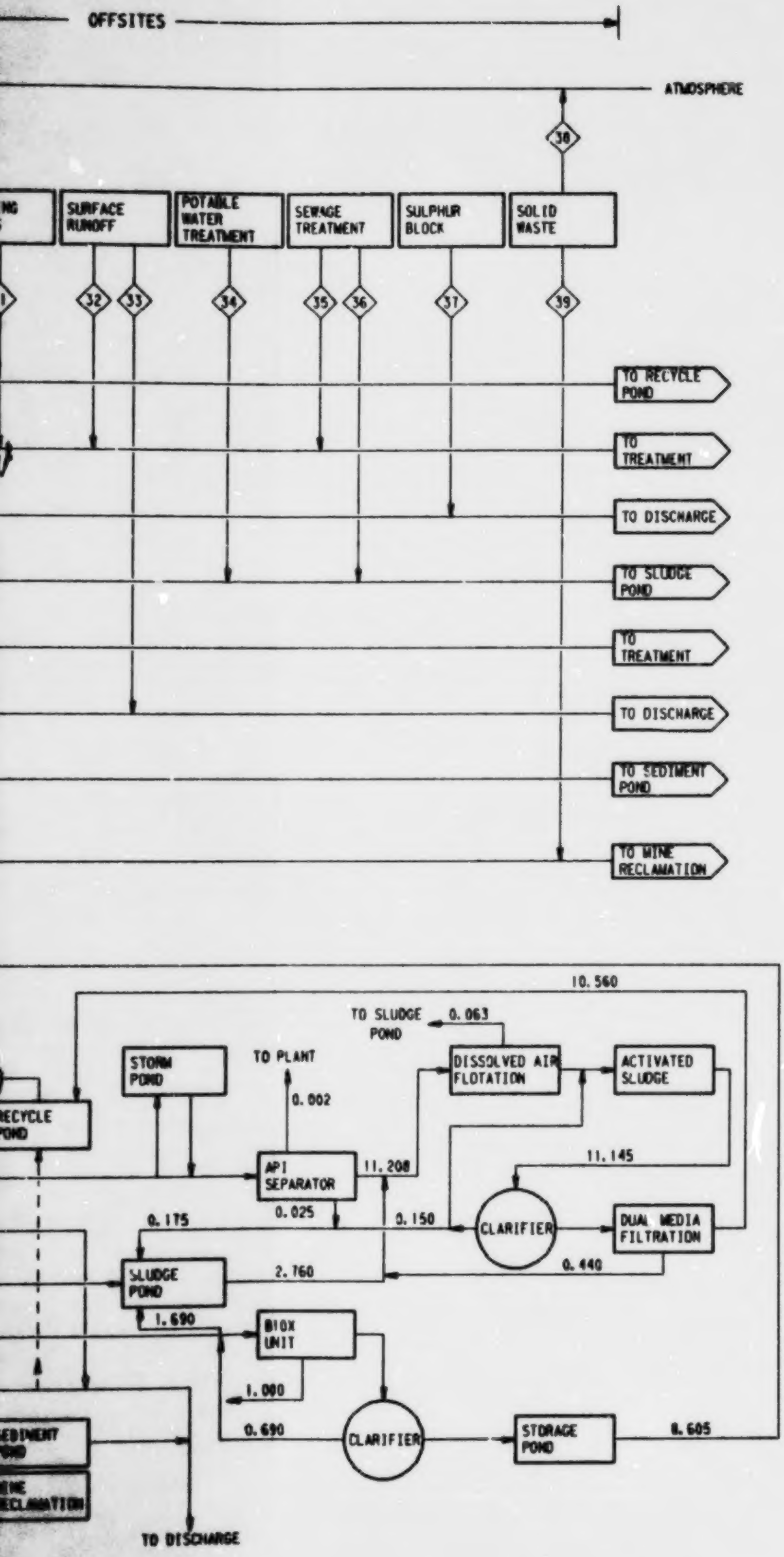

MINING
EXTRACTION/PRIMARY UPGRADING
SECONDARY UPGRADING
UTILITIES
OFFSITES
ATMOSPHERE
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
DIRECT COKING
STEAM GENERATION
CALCINATING PLANT
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
SUPERHEATERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
SULPHUR BLOCK
SOLID WASTE
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
SOUR WATERS SEWER
DRAINAGE DITCH
MINE DRAINAGE
SOLIDS
TO SULPHUR BLOCK
TO OFFSITE TREATMENT & DISPOSAL

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	TOTAL+ ANNUAL FLOW	TOTAL FLOW PER SD
ATMOSPHERIC EMISSIONS $10^6 m^3/sd$	0.023									X	0.013			143.5			1.915	1.403				19.82		1.941				0.104										0.018		5.20E10	168.7
RECYCLE SEWER $10^3 m^3/sd$																0.780							0.140																	2.84E5	0.920
PROCESS WASTE SEWER $10^3 m^3/sd$																					2.304									0.259	1.046	3.265			1.140		0.029			2.27E6	8.043
EFFLUENT SEWER $10^3 m^3/sd$																									16.84		3.403													5.91E6	20.243
SLUDGE SEWER $10^3 m^3/sd$																																		0.060		0.009				2.52E4	0.069
SOUR WATER SEWER $10^3 m^3/sd$															10.10					1.565																				3.60E6	11.665
DRAINAGE DITCH $10^3 m^3/sd$			1.529	6.700				1.453	0.614																								0.653							3.35E6	10.948
MINE DRAINAGE $10^3 m^3/sd$					5.050																																			8.57E5	5.050
SOLIDS t/sd		0.725				27300	154000					6557	189530													45.13													1.663	8.79E7	377434
OTHER SOLIDS t/sd																			445.4																					1.42E5	445.4
OTHER LIQUIDS $10^3 m^3/sd$																													0.051											2.05E3	0.051

X NOT QUANTIFIED

+ UNITS FOR TOTAL ANNUAL FLOW
ATMOSPHERIC EMISSIONS m^3/yr
LIQUID STREAMS m^3/yr
SOLIDS t/yr


TO EXTRACTION
10.
TO SLUDGE POND
0.063
DISSOLVED AIR FLOTATION
TO PLANT
STORM POND
TO PLANT
0.002
RECYCLE POND
API SEPARATOR
11.208
0.175
0.025
0.150
CLARIFIER
SLUDGE POND
2.760
1.690
BIOX UNIT
1.000
0.690
CLARIFIER
STORAGE POND
SEDIMENT POND
MINE RECLAMATION
TO DISCHARGE


OFFSITES
ATMOSPHERE
38
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
SULPHUR BLOCK
SOLID WASTE
32
33
34
35
36
37
39
TO RECYCLE POND
TO TREATMENT
TO DISCHARGE
TO SLUDGE POND
TO TREATMENT
TO DISCHARGE
TO SEDIMENT POND
TO MINE RECLAMATION
10.560
TO SLUDGE POND
0.063
DISSOLVED AIR FLOTATION
ACTIVATED SLUDGE
STORM POND
TO PLANT
0.002
RECYCLE POND
API SEPARATOR
11.208
11.145
0.175
0.025
0.150
CLARIFIER
DUAL MEDIA FILTRATION
SLUDGE POND
2.760
0.440
1.690
BIOX UNIT
1.000
0.690
CLARIFIER
STORAGE POND
8.605
SEDIMENT POND
MINE RECLAMATION
TO DISCHARGE

◇	WASTE STREAM
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	SPENT SAND
14	FLUE GAS
15	WASTEWATER
16	BLOWDOWN
17	FLUE GAS
18	EMISSIONS
19	SULPHUR
20	SWS WASTEWATER
21	CONDENSATE
22	FLUE GAS
23	BLOWDOWN
24	FLUE GAS
25	BLOWDOWN
26	SOFTENER SOLIDS
27	REGENERANT WASTE
28	EMISSIONS
29	TANK BOTTOMS
30	CONDENSATE
31	WASHDOWN
32	INPLANT RUNOFF
33	CLEAN RUNOFF
34	ALUM SLUDGE
35	EFFLUENT
36	DIGESTED SLUDGE
37	BLOCK RUNOFF
38	INCINERATOR EMIS
39	NONCOMBUSTIBLES

FIGURE 3-11 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 1: DIRECT COKING

MONENCO CONSULTANTS LIMITED

AREA	PROCESS	WASTE STREAM	◇	FLOW m^3/sd	TEMP. °C	DENSITY kg/m^3	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3.	TKN-
MINING	DEWATERING	SHALLOW AQUIFER	3	258		1000	7.6						295 76					
		BASAL AQUIFER	4	1000		1005	7.4						1400 1400					
		MINE WATER	5	848		1000	8.3			12 10.2							.28 .237	
	OVERBURDEN	MUSKEG RUNOFF	8	597		1000	7.3		34 20.3	8 4.78		64.6 38.6	78.7 47					.35 .209
		SUBSOIL RUNOFF	9	0														
EXTRACTION	HOT WATER EXTRACTION	WET TAILINGS	13	4.00E4	65	1232	8.5	6.09E5 2.97E7										
	FROTH TREATMENT	WET TAILINGS	15	3023	75	1079	8	8.31E5 2.51E6										
UPGRADING	DILUENT RECOVERY	WASTEWATER	17	363	80	1000										TRACE	TRACE	
	SOUR WATER STRIPPER	SWS WASTEWATER	21	629	140	1000	8.1		295 185		204 128					5 3.14	50 31.4	
	HYDROGEN PLANT	CONDENSATE	22	370		1000								TRACE	19 7.03			
	UPGRADING STEAM	BLOWDOWN	24	36	174	1000	9.5											
UTILITIES	BOILER PLANT	BLOWDOWN	25	75	174	1000	9.5					400 29.8						
	CO BOILERS	PRESCRUBBER BD	28	233		1000												
		FGD BYPRODUCT [1]	29	86	45	1020		7.71E5 6.62E5										
	COKE BOILERS	ASH SLUICE BD	33	55	71	1000	6.4			170 9.33								11.5 .631
	COKE BOILERS	PRESCRUBBER BD	34	180		1000												
		FGD BYPRODUCT [1]	35	341	45	1052		7.71E5 2.63E5										
	COOLING TOWER	BLOWDOWN	37	730	24	1000	7.5				50 36.5	50 36.5					10 7.3	
	WATER T'MENT PLANT	REGENERANT WASTE	39	540		1000	7						145 78.3					
OFFSITES	TANKAGE	TANK BOTTOMS	41	6		1100		4.33E5 2648										
	CONDENSATE LEAKAGE	CONDENSATE	42	39		1000						400 15.6						
	BUILDING DRAINS	WASHDOWN	43	654		1000	8.1						158 103				.12 .078	1.2 .785
	SURFACE RUNOFF	INPLANT RUNOFF	44	2245		1000	7.6		511 1146	10 22.5	74.1 166	90 202						7.07 15.9
		CLEAN RUNOFF	45	490		1000	7.6		511 250		74.1 36.3							7.07 3.46
	POTABLE WATER T'MENT	ALUM SLUDGE	46	30		1000		9.70E5 2.91E4										
	SEWAGE TREATMENT	EFFLUENT	47	570		1000					25 14.3							
		DIGESTED SLUDGE	48	5		1022		9.49E5 4327										
	COKE STORAGE	COKE SLUICE BD	49	55		1000	7.8			170 9.33								11.5 .631
	SULPHUR STORAGE	BLOCK RUNOFF	50	12		1000	6											

[1] ALSO CONTAINS 19.2%wt NH_4HSO_3 AND 7.5%wt $(NH_4)_2SO_3$

MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

COD	TOC	BOD$_5$	TOTAL ALK.	HCO$_3$	H$_2$	CO$_2$	H$_2$S	NH$_3$.	TKN	NO$_3$	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	SOLVENT	OIL & GREASE	PHENOL	DEA	SO$_4$	SUL-PHIDES	S$_2$O$_3$	PO$_4$	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
				295 76						7 1.8			467 120									11 2.83				34 8.75				68 17.5	24 6.18		72 18.5	3 .773												6 1.55			
				1440 1440									3770 3770									55 55	23.5 23.5			1060 1060				55 55	30 30		1137 1137					.9 .9			.5 .5								
	12 10.2							.28 .237				6.5 5.51	400 339						3 2.54								.23 .195			99.7 84.5	24.8 21	.31 .263	66 56	2.87 2.43			.19 .161		.004 .003	.007 .006	.85 .721		.021 .018	.011 .009		8.25 7	.39 .331		.046 .039
34 20.3	8 4.78		64.6 38.6	78.7 47					.35 .209			365 218	10 5.97									.1 .06				1.7 1.01	.06 .036			16.5 9.85	4.5 2.69		4.9 2.92	.5 .298												2.2 1.31			
												6.17E5 3.01E7			6776 3.30E5																																		
												2.02E5 6.10E5			2.70E4 8.15E4		1.94E4 5.87E4																																
							TRACE	TRACE											TRACE																														
295 185		204 128					5 3.14	50 31.4				10 6.29								12 7.55		33 20.8		150 94.3		117 73.6		.1 .063	.36 .226	9 5.66									.07 .044		8.8 5.53					2.6 1.63			
					TRACE	19 7.03										TRACE																																	
													120 4.32													9 .324							14 .504													6 .216			
			400 29.8									150 11.2	2500 186																	500 37.3																35 2.61			
												321 74.8																																					
	170 9.33								11.5 .631			2060 113	775 42.5						10 .549	.062 .003			.1 .005		2.18 .12					17.2 .944	7.63 .419	.44 .024	255 14	13.8 .758	21.9 1.2	.08 .004	.75 .041	.25 .014	.049 .003	.2 .011	19.7 1.08	TRACE	.12 .007	.28 .015	.02 .001	66.2 3.63	.34 .019	.87 .048	.12 .007
												1215 228																																					
		50 36.5	50 36.5					10 7.3				160 117	725 529						10 7.3			290 212			TRACE	30 21.9				170 124	40 29.2	.24 .175	95 69.4	8 5.84	1.84 1.34		.64 .467		.032 .023	TRACE	4.9 3.58	.2 .146	.044 .032			36 26.3			
				145 78.3									6490 3505									3741 2020				481 260				460 248	138 74.5		1398 755	25 13.5												103 55.6			
											9.13E4 558								5.75E5 3515																														
			400 15.6									1000 38.9	2500 97.3						1000 38.9											150 5.83																35 1.36			
				158 103				.12 .078	1.2 .785	.046 .03		1000 654	200 131						1000 654	3 1.96	270 177	15.1 9.88	32 20.9		1.05 .687	7.7 5.04	.11 .072			41.8 27.3	9 5.89		23.5 15.4	1.7 1.11			.16 .105									12 7.85			
511 146	10 22.5	74.1 166	90 202						7.07 15.9	3.17 7.12		1170 2627	350 786						200 449	.025 .056					1.6 3.59	52 117				15 33.7	5 11.2		15 33.7												52 117				
11 250		74.1 36.3							7.07 3.46	3.17 1.55		660 323	200 98													26 12.7				15 7.35	5 2.45		15 7.35																
												3.00E4 900																																					
		25 14.3										25 14.3							25 14.3																														
												5.11E4 233																																					
	170 9.33								11.5 .631			1680 92.2	835 45.8						10 .549	.062 .003			.1 .005		2.18 .12					17.2 .944	7.63 .419	.44 .024	255 14	13.8 .758	21.9 1.2	.08 .004	.75 .041	.25 .014	.049 .003	.2 .011	19.7 1.08	TRACE	.12 .007	.28 .015	.02 .001	66.2 3.63	.34 .019	.87 .048	.12 .007
												280 2.4												TRACE																									

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L	500
LOADING kg/sd	1440

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-21

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION 11 HOT WATER EXTRACTION/FLUID COKING
CO & COKE BOILERS
MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY	SPENT CA'LYST	TOTAL ORG.	TOTAL INORG.
MINING	SITE PREPARATION	ASH	2	122		400		5000 .609				5.90E4 7.19								
	OVERBURDEN	MUSKEG	6	4.50E6		840	7.6												9.76E5 4.47E6	2.40E4 1.10E5
		SUBSOIL	7	2.59E7		1600	7.5								6.30E5 1.63E7	2.07E5 5.37E6	1.62E5 4.20E6			
EXTRACTION	FEED SYSTEM	REJECTS	12	1.48E6	82	1484	8.5	1.19E5 1.76E5	1.50E4 2.22E4						8.37E5 1.24E6	8661 1.28E4	2.08E4 3.07E4			
UPGRADING	FLUID COKING	NET COKE	18	2.70E4		1290		1000 27				7.10E4 1917								
	SULPHUR PLANT	SULPHUR	20	1.26E5		2046		100 12.6				2 .251								
UTILITIES	CO BOILERS	FLY ASH	27	8129	430	2100	8.5													
	COKE BOILERS	BOTTOM ASH	31	6451	80	2400	8													
		FLY ASH	32	2.63E4	430	2100	8.5													
	WATER T'MENT PLANT	SOFTENER SOLIDS	38	7162		2040		4.00E5 2865												
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	52	831		4700						5.49E5 456								

AREA	PROCESS	WASTE STREAM	◇	LIME	$CaCO_3$	$CaSO_4$	METALS	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo
MINING	SITE PREPARATION	ASH	2						1.10E5 13.4					8.50E5 104	2.53E5 30.8				6.40E4 7.8		2.40E4 2.93		4.10E4 5	1.50E4 1.83	
	OVERBURDEN	MUSKEG	6																						
		SUBSOIL	7																						
EXTRACTION	FEED SYSTEM	REJECTS	12																						
UPGRADING	FLUID COKING	NET COKE	18					.4 .011	6930 187			30 .81		7.70E5 2.08E4	602 16.3	10 .27	51 1.38	11 .297	2570 69.4	1.45E4 392		4.35E4 1175	272 7.34	49 1.32	121 3.27
	SULPHUR PLANT	SULPHUR	20											15 1.88											
UTILITIES	CO BOILERS	FLY ASH	27						3.31E5 2687						3.31E4 269				9.92E4 806						
	COKE BOILERS	BOTTOM ASH	31						2.71E5 1746						4.12E4 266				8.60E4 555		2.14E4 138		1.43E4 92.2	2600 16.8	
		FLY ASH	32						3.31E5 8709						3.31E4 871				9.92E4 2613						
	WATER T'MENT PLANT	SOFTENER SOLIDS	38		6.00E5 4297																				
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	52				4.51E5 375																		

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m³	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
MINING	SITE PREPARATION	EMISSIONS	1	3943	400	101	1.25E6	1.12E5 441	3.32E5 1309						7.07E5 3104			1.32E4 52.2		550 2.17				
	FUGITIVE EMISSION	DUST *	10																					
		DIESEL EMISSIONS	11	2000	540	101	1.11E6		560 1.12	1.02E4 20.4	6.66E4 133	7660 15.3	95.8 .192		8.91E5 1782	3.75E4 75	330 .66	1.50E4 30		1.88E4 37.5	5.46E4 109		5110 10.2	2780 5.56
EXTRACTION	HOT WATER EXTRACTION	STEAM VENTS	14	2.84E5	200	101	7.62E5	7.62E5 2.16E5																
	FROTH TREATMENT	VENTS	16	1715		101	1.47E6	7.72E4 132	798 1.37		2.58E5 442				7.62E5 1307			1.76E4 30.2				3.50E5 601		
UPGRADING	SULPHUR PLANT	EMISSIONS	19	3.89E5	538	105	1.20E6	3.98E4 1.55E4	9.30E4 3.61E4			634 246	6.77 2.63		1.06E6 4.13E5	211 82.1								
	UPGRADING HEATERS	FLUE GAS	23	3.26E6	400	118	1.24E6	9.13E4 2.97E5	2.75E5 8.96E5		4.19E4 1.37E5	160 521	2 6.51		8.19E5 2.67E6	270 879		1.52E4 4.95E4						
UTILITIES	CO BOILERS	FLUE GAS	26	2.63E6	43	101	1.24E6	6.92E4 1.82E5	2.60E5 6.85E5		1.74E4 4.57E4	853 2242	11 28.9		8.90E5 2.34E6	221 581	TRACE	5854 1.54E4		3.1 8.15				
	COKE BOILERS	FLUE GAS	30	8.00E6	43	101	1.24E6	6.92E4 5.54E5	2.38E5 1.91E6		4.71E4 3.77E5	1001 8009	12.6 101		8.70E5 6.96E6	455 3639	TRACE	1.77E4 1.42E5		3.3 26.4				
	PG SUPERHEATERS	FLUE GAS	36	4.11E5	68	101	1.18E6	1.32E5 5.43E4	1.71E5 7.01E4		2.40E4 9873	138 56.8	1.75 .719		8.40E5 3.45E5			1.54E4 6329	4.38 1.8					
OFFSITES	FLARE	EMISSIONS	40	5.19E4	1000	101	1.19E6	1.32E5 6873	1.95E5 1.01E4			600 31.2	8 .415		8.44E5 4.38E4			1.42E4 735						
	SOLIG WASTE	INCINERATOR EMIS	51	8890	650	103	1.23E6	1.22E5 1082	3.06E5 2722			122 1.08	1.5 .013		7.99E5 7102	1105 9.82				123 1.09				

* NOT CHARACTERIZED

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS NOTED OTHERWISE

Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
		6.40E4 7.8		2.40E4 2.93		4.10E4 5	1.50E4 1.83			8.00E4 9.75				2.10E4 2.56			3.20E5 39	8000 .975		
51 1.38	11 .297	2570 69.4	1.45E4 392		4.35E4 1175	272 7.34	49 1.32	121 3.27	6200 167	370 9.99	660 17.8		20 .54	7.90E4 2133				1160 31.3	1590 42.9	13 .351
														1.00E6 1.26E5						
		9.92E4 806								8264 67.2							5.29E5 4300			
		8.60E4 555		2.14E4 138		1.43E4 92.2	2600 16.8			9900 63.9	1.53E4 98.7	1100 7.1					4.30E5 2774	3.70E4 239	6.25E4 403	
		9.92E4 2613								8264 218							5.29E5 1.39E4			

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg LOADING kg/sd	6.00E5 4.85E8

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

DATA PRESENTATION: GASES

PARAMETER	CO_2
CONCENTRATION mg/m^3 LOADING kg/sd	4000 1.42E6

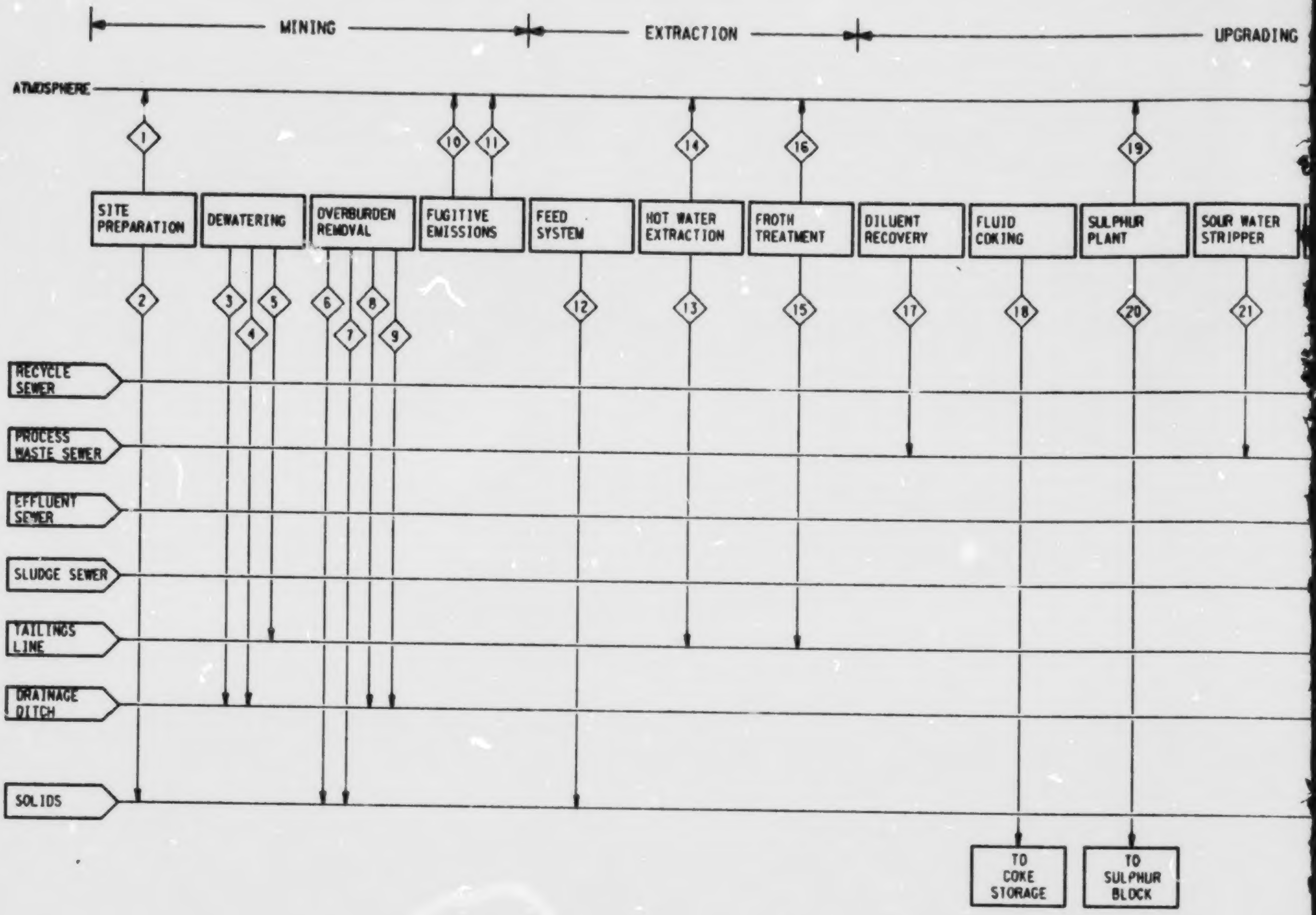
UNITS AS ABOVE UNLESS
NOTED OTHERWISE

MATRIX 3-22

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 11 HOT WATER EXTRACTION/FLUID COKING
CO & COKE BOILERS

MONENCO CONSULTANTS LIMITED


MINING
EXTRACTION
UPGRADING
ATMOSPHERE
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
HOT WATER EXTRACTION
FROTH TREATMENT
DILUENT RECOVERY
FLUID COKING
SULPHUR PLANT
SOUR WATER STRIPPER
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
TAILINGS LINE
DRAINAGE DITCH
SOLIDS
TO COKE STORAGE
TO SULPHUR BLOCK

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
ATMOSPHERIC EMISSIONS $10^6 m^3/sd$	0.004									✳	0.002			0.284		0.002			0.389				3.257			2.628
RECYCLE SEWER $10^3 m^3/sd$																								0.036	0.075	
PROCESS WASTE SEWER $10^3 m^3/sd$																	0.363				0.629	0.370				
EFFLUENT SEWER $10^3 m^3/sd$																										
SLUDGE SEWER $10^3 m^3/sd$																										
TAILINGS LINE $10^3 m^3/sd$					0.848								48.77		3.023											
DRAINAGE DITCH $10^3 m^3/sd$			0.258	1.000				0.597	0																	
SOLIDS t/sd		0.122				4580	25900					1477														
OTHER SOLIDS t/sd																		27		125.6						
OTHER LIQUIDS $10^3 m^3/sd$																										

✳ NOT QUANTIFIED

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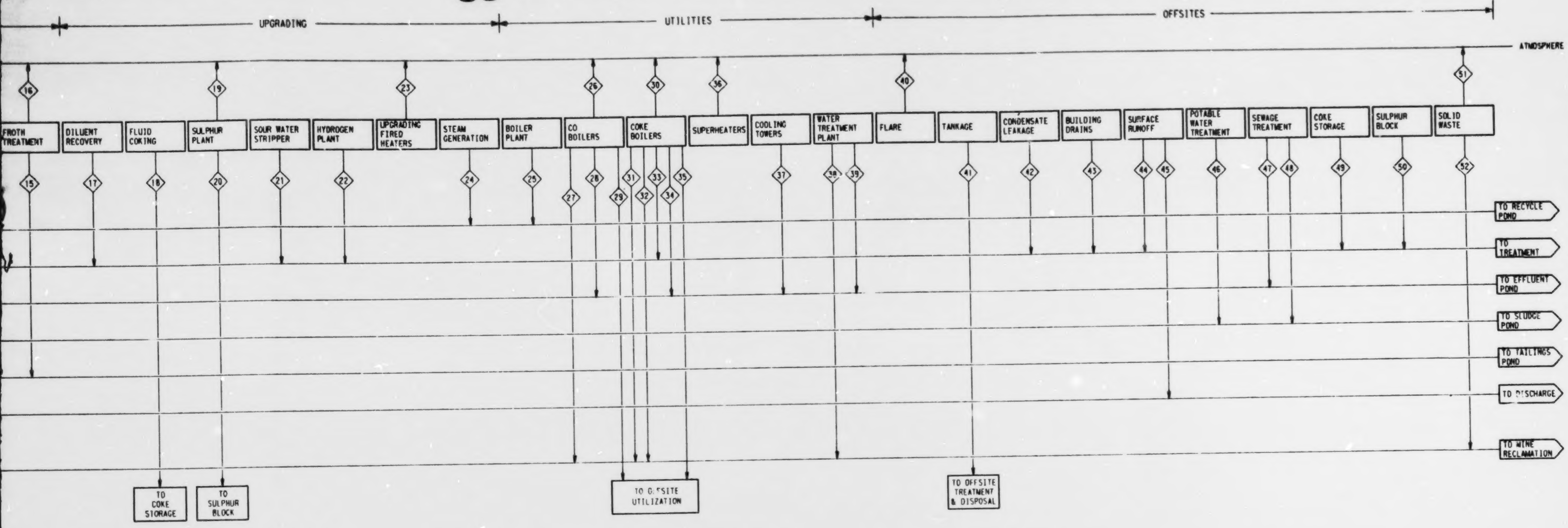
UPGRADING
UTILITIES
OFFSITES
ATMOSPHERE
FROTH TREATMENT
DILUENT RECOVERY
FLUID COKING
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
BOILER PLANT
CO BOILERS
COKE BOILERS
SUPERHEATERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
COKE STORAGE
SULPHUR BLOCK
SOLID WASTE
TO RECYCLE POND
TO TREATMENT
TO EFFLUENT POND
TO SLUDGE POND
TO TAILINGS POND
TO DISCHARGE
TO MINE RECLAMATION
TO COKE STORAGE
TO SULPHUR BLOCK
TO OFFSITE UTILIZATION
TO OFFSITE TREATMENT & DISPOSAL

WASTE STREAM	
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	WET TAILINGS
14	STEAM VENTS
15	WET TAILINGS
16	VENTS
17	WASTEWATER
18	NET COKE
19	EMISSIONS
20	SULPHUR
21	SWS WASTEWATER
22	CONDENSATE
23	FLUE GAS
24	BLOWDOWN
25	BLOWDOWN
26	FLUE GAS
27	FLY ASH
28	PRESCRUBBER BD
29	FGD BYPRODUCT
30	FLUE GAS
31	BOTTOM ASH
32	FLY ASH
33	ASH SLUICE BD
34	PRESCRUBBER BD
35	FGD BYPRODUCT
36	FLUE GAS
37	BLOWDOWN
38	SOFTENER SOLIDS
39	REGENERANT WASTE
40	EMISSIONS
41	TANK BOTTOMS
42	CONDENSATE
43	WASHDOWN
44	INPLANT RUNOFF
45	CLEAN RUNOFF
46	ALUM SLUDGE
47	EFFLUENT
48	DIGESTED SLUDGE
49	COKE SLUICE BD
50	BLOCK RUNOFF
51	INCINERATOR EMIS
52	NONCOMBUSTIBLES

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	TOTAL + ANNUAL FLOW	TOTAL FLOW PER SD
	0.002			0.389				3.257			2.628				7.998						0.411				0.052											0.009		4.56E9	15.036
									0.036	0.075																												3.34E4	0.111
		0.363				0.629	0.370											0.055									0.039	0.654	2.245					0.055	0.012			1.17E6	4.422
													0.233						0.188			0.730		0.540								0.570						7.43E5	2.261
																															0.030		0.005					1.28E4	0.035
3.023																																						1.53E6	52.64
																														0.490								6.53E5	2.088
												8.1				6.45	26.35						7.162														0.831	5.12E6	32006
			27		125.6																																	4.87E4	152.6
														0.086						0.341						0.006												1.27E5	0.433

+ UNITS FOR TOTAL ANNUAL FLOW
ATMOSPHERIC EMISSIONS m³/yr
LIQUID STREAMS m³/yr
SOLIDS t/yr

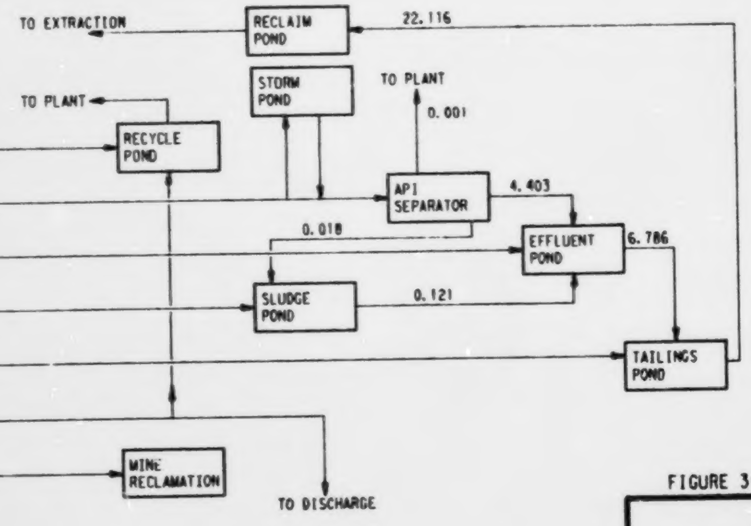
TO EXTRACTION
RECLAIM POND
22.116
STORM POND
TO PLANT
0.001
TO PLANT
RECYCLE POND
API SEPARATOR
4.403
0.018
EFFLUENT POND
6.786
SLUDGE POND
0.121
TAILINGS POND
MINE RECLAMATION
TO DISCHARGE

FIGURE 3-12 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS FROM A MINING OIL SANDS COMPLEX
OPTION II HOT WATER EXTRACTION/FLUID COKING/ CO & COKE BOILERS
MONENCO CONSULTANTS LIMITED

N08121.PFD F24

MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3	TKN	NO_3	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	SOLVENT	OIL & GREASE	PHENOL	DEA	SO_4	SULPHIDES	S_2O_3	PO_4	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K
MINING	DEWATERING	SHALLOW AQUIFER	3	223		1000	7.6						295 65.7						7 1.56			467 104									11 2.45				34 7.57				58 15.1	24 5.34		72 16	3 .668
		BASAL AQUIFER	4	1000		1005	7.4						1440 1440									3778 3778									55 55	23.5 23.5			1060 1060				55 55	30 30		1137 1137	
		MINE WATER	5	734		1000	8.3			12 8.01							.28 .206				6.5 4.77	400 294						3 2.2								.23 .169			99.7 73.2	24.8 18.2	.31 .228	66 48.4	2.87 2.11
	OVERBURDEN	MUSKEG RUNOFF	8	461		1000	7.3		34 15.7	8 3.69		64.6 29.8	78.7 36.3					.35 .161			365 168	10 4.61									.1 .046				1.7 .783	.06 .028			16.5 7.6	4.5 2.07		4.9 2.26	.5 .23
		SUBSOIL RUNOFF	9	217		1000	7.6				30 6.5										6123 1326	150 32.5													10 2.17				15 3.25	5 1.08		15 3.25	
EXTRACTION	HWE/FILTRATION	FILTRATE	15	2.42E4	65	1015	8														4.06E4 9.82E5			1440 3.48E4		205 4956																	
UPGRADING	DILUENT RECOVERY	WASTEWATER	17	307	88	1000										TRACE	TRACE											TRACE															
	SOUR WATER STRIPPER	SWS WASTEWATER	21	430	140	1000	8.1		295 127		204 87.6					5 2.15	50 21.5				10 4.3								12 5.16		33 14.2		150 64.4		117 50.3		.1 .043	.36 .155	9 3.87				
	HYDROGEN PLANT	CONDENSATE	24	307		1000								TRACE	19 5.83										TRACE																		
		WASTEWATER	25	178		1000	7.9		4050 721			1252 223				5 .89	144 25.6		3 .534						32.5 5.79				730 130		120 21.4			3.5 .623			.4 .071	31 5.52					
		STRIPPED WATER	26	16	140	1000	8		295 4.72		204 3.26						50 .8				10 .16								12 .192				160 2.56				.1 .002	.4 .006	9 .144				
	UPGRADING STEAM	BLOWDOWN	30	35	174	1000	9.5															120 4.2													9 .315							14 .49	
UTILITIES	BOILER PLANT	BLOWDOWN	31	59	174	1000	9.5					400 23.4									150 8.78	2500 146																	500 29.3				
	COOLING TOWER	BLOWDOWN	35	830	24	1000	7.5				50 41.5	50 41.5					10 8.3				160 133	725 602						10 8.3			290 241			TRACE	30 24.9				170 141	40 33.2	.24 .199	95 78.9	8 6.64
	WATER T'MENT PLANT	REGENERANT WASTE	37	424		1000	7						145 61.5									6490 2752									3741 1586				481 204				460 195	130 58.5		1350 593	25 10.6
OFFSITES	TANKAGE	TANK BOTTOMS	39	5		1100		4.33E5 2223												9.13E4 468								5.75E5 2951															
	CONDENSATE LEAKAGE	CONDENSATE	40	39		1000						400 15.6									1000 38.9	2500 97.3						1000 38.9											150 5.83				
	BUILDING DRAINS	WASHDOWN	41	654		1000	8.1						158 103				.12 .078	1.2 .785	.046 .03		1000 654	200 131						1000 654	3 1.96	270 177	15.1 9.88	32 20.9		1.05 .687	7.7 5.04	.11 .072			41.8 27.3	9 5.89		23.5 15.4	1.7 1.11
	SURFACE RUNOFF	INPLANT RUNOFF	42	2245		1000	7.6		511 1146	10 22.5	74.1 166	90 202						7.07 15.9	3.17 7.12		1170 2627	350 786						200 449	.025 .056					1.6 3.59	52 117				15 33.7	5 11.2		15 33.7	
		CLEAN RUNOFF	43	490		1000	7.6		511 250		74.1 36.3							7.07 3.46	3.17 1.55		660 323	200 98													26 12.7				15 7.35	5 2.45		15 7.35	
	POTABLE WATER T'MENT	ALUM SLUDGE	44	30		1000		9.70E5 2.91E4													3.00E4 900																						
	SEWAGE TREATMENT	EFFLUENT	45	570		1000					25 14.3										25 14.3							25 14.3															
		DIGESTED SLUDGE	46	5		1022		9.49E5 4327													5.11E4 233																						
	SULPHUR STORAGE	BLOCK RUNOFF	47	13		1000	6														200 2.58												TRACE										

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
	34 7.57				60 15.1	24 5.34		72 16	3 .668												6 1.34			
	1060 1060				55 55	30 30		1137 1137					.9 .9			.5 .5								
		.23 .169			99.7 73.2	24.8 18.2	.31 .228	66 48.4	2.87 2.11			.19 .139		.004 .003	.007 .005	.85 .624		.021 .015	.011 .008		8.25 6.06	.39 .286		.046 .034
	1.7 .783	.06 .028			16.5 7.6	4.5 2.07		4.9 2.26	.5 .23												2.2 1.01			
	10 2.17				15 3.25	5 1.08		15 3.25																
	117 50.3		.1 .043	.36 .155	9 3.87									.07 .03		8.8 3.78					2.6 1.12			
5 23			.4 .071	31 5.52																				
			.1 .002	.4 .006	9 .144									.7 .011		8.8 .141					2.6 .042			
	9 .315							14 .49													6 .21			
					500 29.3																35 2.05			
CE	30 24.9				170 141	40 33.2	.24 .199	95 78.9	8 6.64	1.84 1.53		.64 .531		.032 .027	TRACE	4.9 4.07	.2 .166	.044 .037			36 29.9			
	481 204				460 195	138 58.5		1398 593	25 10.6												103 43.7			
					150 5.83																35 1.36			
05 37	7.7 5.04	.11 .072			41.8 27.3	9 5.89		23.5 15.4	1.7 1.11			.16 .105									12 7.85			
6 59	52 117				15 33.7	5 11.2		15 33.7												52 117				
	26 12.7				15 7.35	5 2.45		15 7.35																

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L	500
LOADING kg/sd	1440

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-23

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS FROM A MINING OIL SANDS COMPLEX

OPTION 12 HOT WATER EXTRACTION/TAILINGS FILTRATION/H-OIL/ PARTIAL OXIDATION OF PITCH

MONENCO CONSULTANTS LIMITED

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AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT
MINING	SITE PREPARATION	ASH	2	106		400		5000 .527				5.90E4 6.22				
	OVERBURDEN	MUSKEG	6	3.96E6		840	7.6									
		SUBSOIL	7	2.24E7		1600	7.5								6.30E5 1.41E7	2.07E5 4.64E6
EXTRACTION	FEED SYSTEM	REJECTS	12	1.25E6	82	1484	8.5	1.19E5 1.49E5	1.50E4 1.87E4						8.37E5 1.05E6	8661 1.00E4
	HWE/FILTRATION	DRY TAILINGS	13	2.94E7	65	1600		1.30E5 4.06E6	1.07E4 3.15E5	1520 4.47E4					8.21E5 2.42E7	8500 2.50E5
UPGRADING	HYDROVISBREAKING	SPENT CATALYST	18	1272		4000										
	SULPHUR PLANT	SULPHUR	20	1.46E5		2046		100 14.6				2 .293				
	HYDROGEN PLANT	SLAG	27	3.19E4		704		9.10E4 2905				8.96E5 2.86E4				
		CHAR	28	1.99E4		734		5000 99.6				8.58E5 1.71E4				
UTILITIES	WATER T'MENT PLANT	SOFTENER SOLIDS	36	5618		2040		4.00E5 2247								
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	49	831		4700						5.49E5 456				

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STRE

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m³	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx
MINING	SITE PREPARATION	EMISSIONS	1	3412	400	101	1.25E6	1.12E5 382	3.32E5 1133						7.87E5 2686	
	FUGITIVE EMISSION	DUST *	10													
		DIESEL EMISSIONS	11	2000	540	101	1.11E6		560 1.12	1.02E4 20.4	6.66E4 133	7660 15.3	95.8 .192		8.91E5 1782	3.75E4 75
EXTRACTION	HWE/FILTRATION	STEAM VENTS	14	2.40E5	200	101	7.62E5	7.62E5 1.83E5								
	FROTH TREATMENT	VENTS	16	1484		101	1.47E6	7.72E4 114	798 1.18		2.58E5 382				7.62E5 1131	
UPGRADING	SULPHUR PLANT	EMISSIONS	19	4.80E5	538	105	1.22E6	3.85E4 1.85E4	1.49E5 7.14E4			634 304	10.2 4.9		1.03E6 4.94E5	211 101
	OXYGEN PLANT	EMISSIONS	22	398	20	101	1.19E6		716 .285		2.34E4 9.31				1.15E6 457	
	HYDROGEN PLANT	CO2 VENT	23	3.48E5	25	103	1.55E6	1522 530	1.22E6 4.24E5	410 143				1580 550	3.28E5 1.14E5	
	UPGRADING HEATERS	FLUE GAS	29	3.60E6	400	110	1.23E6	9.13E4 3.29E5	2.29E5 8.23E5		4.33E4 1.56E5	30 108	.1 .36		8.47E5 3.05E6	270 972
UTILITIES	NG BOILERS	FLUE GAS	32	4.18E6	177	101	1.18E6	1.22E5 5.10E5	1.51E5 6.30E5		4.32E4 1.81E5				8.51E5 3.55E6	263 1098
	WASTE HEAT BOILERS	FLUE GAS	33	2.42E6	177	101	1.16E6	1.39E5 3.35E5	1.71E5 4.14E5		7523 1.82E4				8.30E5 2.01E6	18.8 45.4
	NG SUPERHEATERS	FLUE GAS	34	1.97E5	177	101	1.18E6	1.32E5 2.60E4	1.63E5 3.21E4		2.33E4 4584				8.44E5 1.66E5	284 55.9
OFFSITES	FLARE	EMISSIONS	38	4.31E4	1000	101	1.18E6	1.43E5 6146	1.82E5 7855			54 2.33	.7 .03		8.36E5 3.61E4	
	SOLID WASTE	INCINERATOR EMIS	48	8890	650	103	1.23E6	1.22E5 1082	3.06E5 2722			122 1.08	1.5 .013		7.99E5 7102	1105 9.82

* NOT CHARACTERIZED

WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY	SPENT CA'LYST	TOTAL ORG.	TOTAL INORG.	LIME	$CaCO_3$	$CaSO_4$	METALS	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
	5000 .527				5.90E4 6.22														1.10E5 11.6					8.50E5 89.7	2.53E5 26.7				6.40E4 6.75		2.40E4 2.53		4.10E4 4.33	1.50E4 1.58			8.00E4 8.44				2.10E4 2.22			3.20E5 33.8	8000 .844		
.6												9.76E5 3.06E6	2.40E4 9.50E4																																		
.5								6.30E5 1.41E7	2.07E5 4.64E6	1.62E5 3.64E6																																					
.5	1.19E5 1.49E5	1.50E4 1.87E4						8.37E5 1.05E6	8661 1.08E4	2.08E4 2.60E4																																					
	1.30E5 4.06E6	1.07E4 3.15E5	1520 4.47E4					8.21E5 2.42E7	8500 2.50E5	2.04E4 6.00E5																																					
											4.32E5 550													1.04E5 234					3000 3.02									5.60E4 71.2			4.60E4 58.5					1.07E5 238	
	100 14.6				2 .293																			15 2.19																	1.00E6 1.46E5						
	9.10E4 2905				8.96E5 2.86E4																			9000 287														2000 63.8								2000 63.8	
	5000 99.6				8.58E5 1.71E4																			1.30E5 2749														2000 39.8								2000 39.8	
	4.00E5 2247														6.00E5 3371																																
					5.49E5 456												4.51E5 375																														

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

SITY $/m^3$	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
5E6	1.12E5 382	3.32E5 1133						7.87E5 2686			1.32E4 45.2		550 1.88				
E6		560 1.12	1.02E4 20.4	6.66E4 133	7660 15.3	95.8 .192		8.91E5 1782	3.75E4 75	330 .66	1.50E4 30		1.88E4 37.5	5.46E4 109		5110 10.2	2780 5.56
E5	7.62E5 1.83E5																
E6	7.72E4 114	798 1.18		2.50E5 382				7.62E5 1131			1.76E4 26.2				3.50E5 520		
E6	3.05E4 1.05E4	1.49E5 7.14E4			634 304	10.2 4.9		1.03E6 4.94E5	211 101								
E6		716 .285		2.34E4 9.31				1.15E6 457			1.93E4 7.7						
E6	1522 530	1.22E6 4.24E5	410 143				1580 550	3.28E5 1.14E5									
E6	9.13E4 3.29E5	2.29E5 8.23E5		4.33E4 1.56E5	30 108	.1 .36		8.47E5 3.05E6	270 972		1.52E4 5.47E4						
E6	1.22E5 5.10E5	1.51E5 6.30E5		4.32E4 1.81E5				8.51E5 3.55E6	263 1098		1.43E4 5.97E4	5.51 23					
E6	1.39E5 3.35E5	1.71E5 4.14E5		7523 1.82E4				8.30E5 2.01E6	18.8 45.4		1.39E4 3.37E4	6 14.5					
E6	1.32E5 2.60E4	1.63E5 3.21E4		2.33E4 4504				8.44E5 1.66E5	284 55.9		1.42E4 2793	5.97 1.17					
E6	1.43E5 6146	1.82E5 7855			54 2.33	.7 .03		8.36E5 3.61E4			1.44E4 619						
E6	1.22E5 1082	3.06E5 2722			122 1.08	1.5 .013		7.99E5 7102	1105 9.82				123 1.09				

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS NOTED OTHERWISE

DATA PRESENTATION: GASES

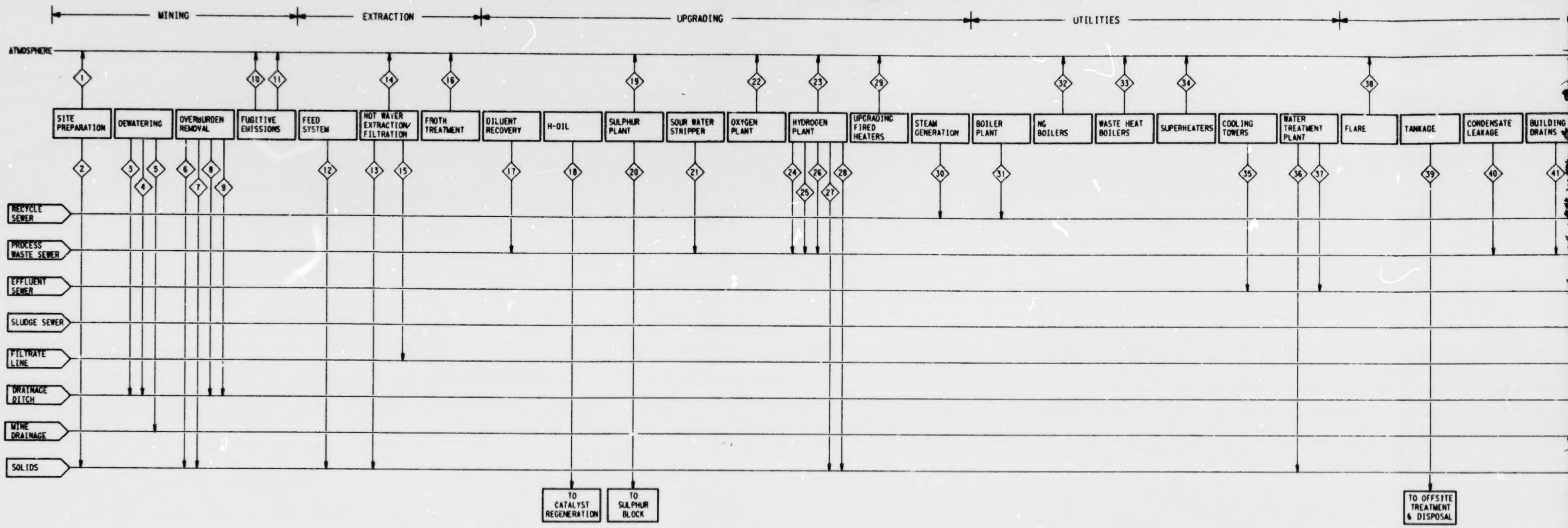
PARAMETER	CO_2
CONCENTRATION mg/m^3	4000
LOADING kg/sd	1.42E6

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-24

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS FROM A MINING OIL SANDS COMPLEX
OPTION 12 HOT WATER EXTRACTION/TAILINGS FILTRATION/H-OIL/ PARTIAL OXIDATION OF PITCH
MONENCO CONSULTANTS LIMITED

MONENCO CONSULTANTS LIMITED


MINING
EXTRACTION
UPGRADING
UTILITIES
ATMOSPHERE
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
HOT WATER EXTRACTION/ FILTRATION
FROTH TREATMENT
DILUENT RECOVERY
H-OIL
SULPHUR PLANT
SOUR WATER STRIPPER
OXYGEN PLANT
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
BOILER PLANT
NG BOILERS
WASTE HEAT BOILERS
SUPERHEATERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
FILTRATE LINE
DRAINAGE DITCH
MINE DRAINAGE
SOLIDS
TO CATALYST REGENERATION
TO SULPHUR BLOCK
TO OFFSITE TREATMENT & DISPOSAL
1
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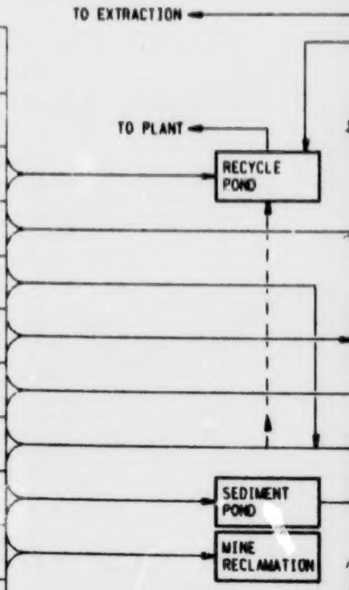
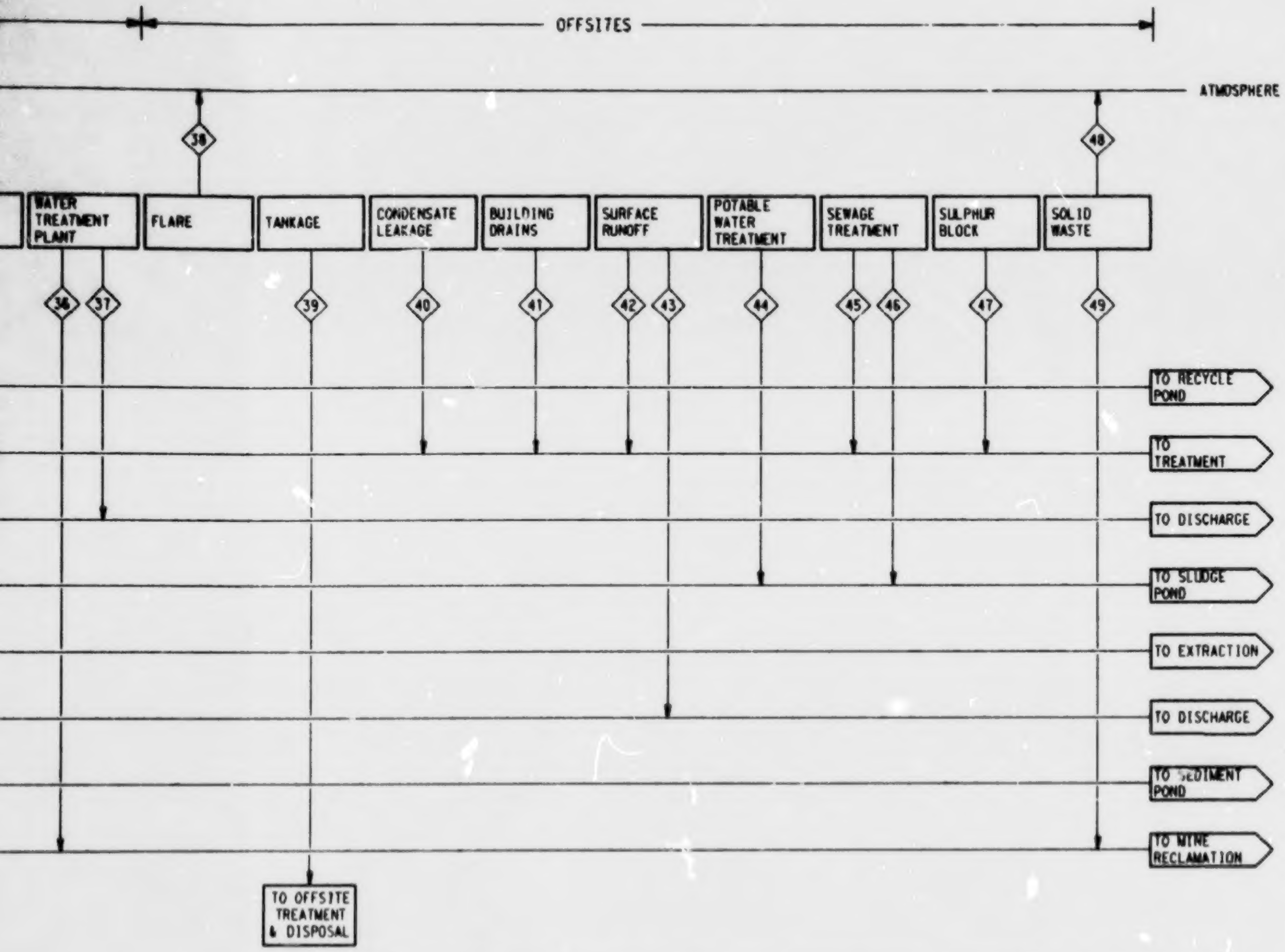
	⟨1⟩	⟨2⟩	⟨3⟩	⟨4⟩	⟨5⟩	⟨6⟩	⟨7⟩	⟨8⟩	⟨9⟩	⟨10⟩	⟨11⟩	⟨12⟩	⟨13⟩	⟨14⟩	⟨15⟩	⟨16⟩	⟨17⟩	⟨18⟩	⟨19⟩	⟨20⟩	⟨21⟩	⟨22⟩	⟨23⟩	⟨24⟩	⟨25⟩	⟨26⟩	⟨27⟩	⟨28⟩	⟨29⟩	⟨30⟩	⟨31⟩	⟨32⟩	⟨33⟩	⟨34⟩	⟨35⟩	⟨36⟩	⟨37⟩	⟨38⟩	⟨39⟩	⟨40⟩	⟨41⟩	⟨42⟩	⟨43⟩	⟨44⟩	⟨45⟩	⟨46⟩	⟨47⟩	⟨48⟩	⟨49⟩	TOTAL* ANNUAL FLOW	TOTAL FLOW PER SD
ATMOSPHERIC EMISSIONS $10^6m^3/sd$	0.003									✻	0.002			0.240		0.001			0.480			.0004	0.348						3.600			4.176	2.417	0.197				0.043										0.009		3.49E6	11.52
RECYCLE SEWER $10^3m^3/sd$																														0.035	0.059																			3.00E4	0.094
PROCESS WASTE SEWER $10^3m^3/sd$																	0.307				0.430			0.307	0.178	0.016														0.039	0.654	2.245			0.570		0.013			1.31E6	4.759
EFFLUENT SEWER $10^3m^3/sd$																																			0.830		0.424													3.66E5	1.254
SLUDGE SEWER $10^3m^3/sd$																																												0.030		0.005				1.28E4	0.035
FILTRATE LINE $10^3m^3/sd$															24.18																																			7.06E6	24.18
DRAINAGE DITCH $10^3m^3/sd$			0.223	1.000				0.461	0.217																																		0.490							6.63E5	2.391
MINE DRAINAGE $10^3m^3/sd$					0.734																																													1.25E5	0.734
SOLIDS t/sd		0.105				3960	22400					1278	30090														31.92	19.92								5.618													0.831	1.32E7	57786
OTHER SOLIDS t/sd																		1.27		146.3																														4.71E4	147.6
OTHER LIQUIDS $10^3m^3/sd$																																							0.005											1.50E2	0.005


TO EXTRACTION
TO PLANT
RECYCLE POND
SEDIMENT POND
MINE RECLAMATION

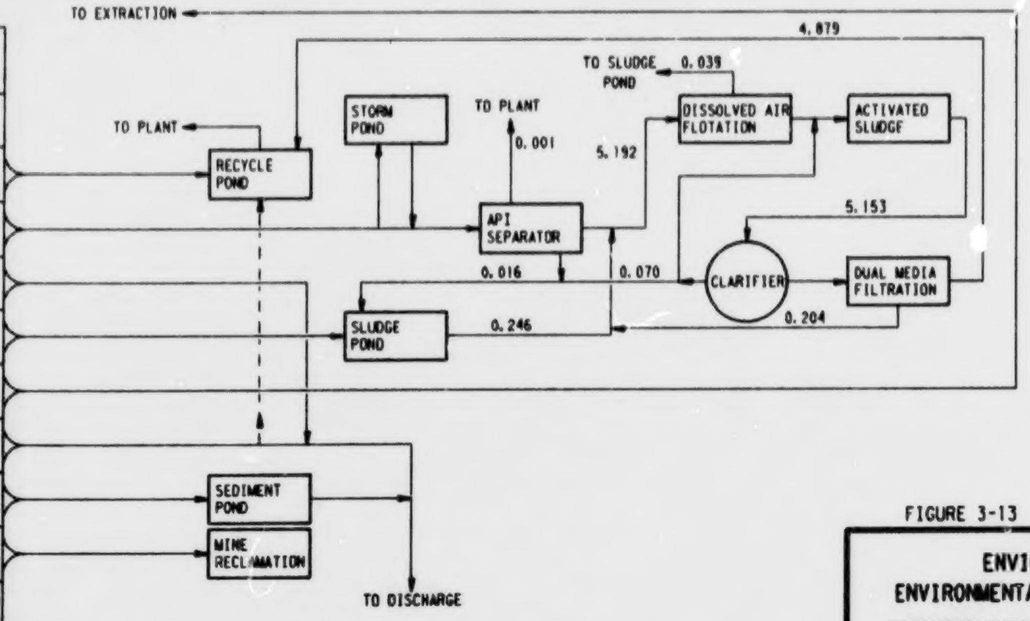
✻ NOT QUANTIFIED

* UNITS FOR TOTAL ANNUAL FLOW: ATMOSPHERIC EMISSIONS m^3/yr
LIQUID STREAMS m^3/yr
SOLIDS t/yr


OFFSITES
ATMOSPHERE
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
SULPHUR BLOCK
SOLID WASTE
36
37
38
39
40
41
42
43
44
45
46
47
48
49
TO RECYCLE POND
TO TREATMENT
TO DISCHARGE
TO SLUDGE POND
TO EXTRACTION
TO DISCHARGE
TO SEDIMENT POND
TO MINE RECLAMATION
TO OFFSITE TREATMENT & DISPOSAL

48	49	TOTAL* ANNUAL FLOW	TOTAL FLOW PER SD
009		3.49E6	11.52
		3.00E4	0.094
		1.31E6	4.759
		3.66E5	1.254
		1.28E4	0.035
		7.06E6	24.18
		6.63E5	2.391
		1.25E5	0.734
	0.031	1.32E7	57786
		4.71E4	147.6
		1.50E2	0.085

UAL FLOW ATMOSPHERIC EMISSIONS m³/yr
LIQUID STREAMS m³/yr
SOLIDS t/yr


TO EXTRACTION
4.879
TO SLUDGE POND
0.039
TO PLANT
TO PLANT
0.001
5.192
RECYCLE POND
STORM POND
API SEPARATOR
DISSOLVED AIR FLOTATION
ACTIVATED SLUDGE
5.153
0.016
0.070
CLARIFIER
DUAL MEDIA FILTRATION
SLUDGE POND
0.246
0.204
SEDIMENT POND
MINE RECLAMATION
TO DISCHARGE

◇	WASTE STREAM
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	DRY TAILINGS
14	STEAM VENTS
15	FILTRATE
16	VENTS
17	WASTEWATER
18	SPENT CATALYST
19	EMISSIONS
20	SULPHUR
21	SWS WASTEWATER
22	EMISSIONS
23	CO2 VENT
24	CONDENSATE
25	WASTEWATER
26	STRIPPED WATER
27	SLAG
28	CHAR
29	FLUE GAS
30	BLOWDOWN
31	BLOWDOWN
32	FLUE GAS
33	FLUE GAS
34	FLUE GAS
35	BLOWDOWN
36	SOFTENER SOLIDS
37	REGENERANT WASTE
38	EMISSIONS
39	TANK BOTTOMS
40	CONDENSATE
41	WASHDOWN
42	INPLANT RUNOFF
43	CLEAN RUNOFF
44	ALUM SLUDGE
45	EFFLUENT
46	DIGESTED SLUDGE
47	BLOCK RUNOFF
48	INCINERATOR EMIS
49	NONCOMBUSTIBLES

FIGURE 3-13 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 12 HOT WATER EXTRACTION/TAILINGS
FILTRATION/H-OIL/
PARTIAL OXIDATION OF PITCH

MONENCO CONSULTANTS LIMITED

AREA	PROCESS	WASTE STREAM	◇	FLOW m^3/sd	TEMP. °C	DENSITY kg/m^3	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3
MINING	DEWATERING	SHALLOW AQUIFER	3	205		1000	7.6						295 60.6				
		BASAL AQUIFER	4	1000		1005	7.4						1440 1440				
		MINE WATER	5	678		1000	8.1			12 8.14							.28 .19
	OVERBURDEN	MUSKEG RUNOFF	8	563		1000	7.3		34 19.2	8 4.51		64.6 36.4	78.7 44.3				
		SUBSOIL RUNOFF	9	0													
EXTRACTION	HOT WATER EXTRACTION	WET TAILINGS	13	3.90E4	65	1232	8.5	6.09E5 2.37E7									
	FROTH TREATMENT	WET TAILINGS	15	2420	75	1079	8	8.31E5 2.01E6									
UPGRADING	DILUENT RECOVERY	WASTEWATER	17	307	88	1000										TRACE	TRACE
	SOUR WATER STRIPPER	SWS WASTEWATER	20	422	140	1000	8.1		295 125		204 86.2					5 2.11	50 21.1
	HYDROGEN PLANT	CONDENSATE	21	512		1000								TRACE	19 9.73		
	UPGRADING STEAM	BLOWDOWN	23	35	174	1000	9.5										
UTILITIES	BOILER PLANT	BLOWDOWN	24	54	174	1000	9.5					400 21.5					
	COOLING TOWER	BLOWDOWN	31	720	24	1000	7.5				50 36	50 36					10 7.2
	WATER T'MENT PLANT	REGENERANT WASTE	33	390		1000	7						145 56.6				
OFFSITES	TANKAGE	TANK BOTTOMS	35	5		1100		4.33E5 2223									
	CONDENSATE LEAKAGE	CONDENSATE	36	39		1000						400 15.6					
	BUILDING DRAINS	WASHDOWN	37	654		1000	8.1						158 103				.12 .078
	SURFACE RUNOFF	INPLANT RUNOFF	38	2245		1000	7.6		511 1146	10 22.5	74.1 166	90 202					
		CLEAN RUNOFF	39	490		1000	7.6		511 250		74.1 36.3						
	POTABLE WATER T'MENT	ALUM SLUDGE	40	30		1000		9.70E5 2.91E4									
	SEWAGE TREATMENT	EFFLUENT	41	570		1000					25 14.3						
		DIGESTED SLUDGE	42	5		1022		9.49E5 4327									
	SULPHUR STORAGE	BLOCK RUNOFF	43	13		1000	6										

WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3	TKN	NO_3	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	SOLVENT	OIL & GREASE	PHENOL	DEA	SO_4	SUL-PHIDES	S_2O_3	PO_4	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
					295 60.6						7 1.44			467 95.9									11 2.26				34 6.98				68 14	24 4.93		72 14.8	3 .616												6 1.23			
					1440 1440									3778 3778									55 55	23.5 23.5			1060 1060				55 55	30 30		1137 1137					.9 .9			.5 .5								
		12 8.14							.28 .19				6.5 4.41	400 271						3 2.03								.23 .156			99.7 67.6	24.8 16.8	.31 .21	66 44.7	2.87 1.95			.19 .129		.004 .003	.007 .005	.85 .575		.021 .014	.011 .007		8.25 5.59	.39 .264		.046 .031
	34 19.2	8 4.51		64.6 36.4	78.7 44.3					.35 .197			365 206	10 5.63									.1 .056				1.7 .958	.06 .034			16.5 9.29	4.5 2.53		4.9 2.76	.5 .282												2.2 1.24			
E5 E7													6.17E5 2.41E7			6776 2.64E5																																		
E5 E6													2.02E5 4.88E5			2.70E4 6.53E4		1.94E4 4.70E4																																
								TRACE	TRACE											TRACE																														
	295 125		204 86.2					5 2.11	50 21.1				10 4.22								12 5.07		33 13.9		150 63.4		117 49.4		.1 .042	.36 .152	9 3.8									.07 .03		8.8 3.72					2.6 1.1			
						TRACE	19 9.73										TRACE																																	
														120 4.2													9 .315							14 .49													6 .21			
				400 21.5									150 8.07	2500 135																	500 26.9																35 1.88			
			50 36	50 36					10 7.2				160 115	725 522						10 7.2			290 209			TRACE	30 21.6				170 122	40 28.8	.24 .173	95 68.4	8 5.76	1.84 1.32		.64 .461		.032 .023	TRACE	4.9 3.53	.2 .144	.044 .032			36 25.9			
					145 56.6									6490 2531									3741 1459				481 188				460 179	138 53.8		1398 545	25 9.75												103 40.2			
E5 23												9.13E4 468								5.75E5 2951																														
				400 15.6									1000 38.9	2500 97.3						1000 38.9											150 5.83																35 1.96			
					158 103				.12 .078	1.2 .785	.046 .03		1000 654	200 131						1000 654	3 1.96	270 177	15.1 9.88	32 20.9		1.05 .687	7.7 5.04	.11 .072			41.8 27.3	9 5.89		23.5 15.4	1.7 1.11			.16 .105									12 7.85			
	511 1146	10 22.5	74.1 166	90 202						7.07 15.9	3.17 7.12		1170 2627	350 786						200 449	.025 .056					1.6 3.59	52 117				15 33.7	5 11.2		15 33.7												52 117				
	511 250		74.1 36.3							7.07 3.46	3.17 1.55		660 323	200 98													26 12.7				15 7.35	5 2.45		15 7.35																
E5 E4													3.00E4 900																																					
			25 14.3										25 14.3							25 14.3																														
E5 7													5.11E4 233																																					
													200 2.52												TRACE																									

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L	500
LOADING kg/sd	1440

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-25

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 13 HOT WATER EXTRACTION/CANMET/
PITCH BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

M00157.CHT F24

MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY	SPENT CA'LYST	TOTAL ORG.	TOTAL INORG.
MINING	SITE PREPARATION	ASH	2	98		400		5000 .488				5.90E4 5.76								
	OVERBURDEN	MUSKEG	6	3.66E6		840	7.6												9.76E5 3.57E6	2.40E4 8.78E4
		SUBSOIL	7	2.07E7		1600	7.5								6.30E5 1.30E7	2.07E5 4.29E6	1.62E5 3.36E6			
EXTRACTION	FEED SYSTEM	REJECTS	12	1.18E6	82	1484	8.5	1.19E5 1.41E5	1.50E4 1.77E4						8.37E5 9.89E5	8661 1.02E4	2.08E4 2.46E4			
UPGRADING	SULPHUR PLANT	SULPHUR	19	1.27E5		2046		100 12.7				2 .255								
UTILITIES	PITCH BOILERS	SPENT BED SOLIDS	26	5.38E4	400	1800														
		FLY ASH	27	2.26E4	430	2100	8.5													
	WATER T'MENT PLANT	SOFTENER SOLIDS	32	5170		2040		4.00E5 2068												
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	45	831		4700						5.49E5 456								

AREA	PROCESS	WASTE STREAM	◇	LIME	$CaCO_3$	$CaSO_4$	METALS	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo
MINING	SITE PREPARATION	ASH	2						1.10E5 10.7				2	8.50E5 83	2.53E5 24.7				6.40E4 6.25		2.40E4 2.34		4.10E4 4	1.50E4 1.46	
	OVERBURDEN	MUSKEG	6																						
		SUBSOIL	7																						
EXTRACTION	FEED SYSTEM	REJECTS	12																						
UPGRADING	SULPHUR PLANT	SULPHUR	19											15 1.91											
UTILITIES	PITCH BOILERS	SPENT BED SOLIDS	26	4.92E5 2.65E4		3.98E5 2.14E4			3.28E4 1764						4986 268				9837 530		2590 139		1730 93.1	315 17	
		FLY ASH	27						3.31E5 7482						3.31E4 748				9.92E4 2245						
	WATER T'MENT PLANT	SOFTENER SOLIDS	32		6.00E5 3102																				
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	45				4.51E5 375																		

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m³	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
MINING	SITE PREPARATION	EMISSIONS	1	3156	400	101	1.25E6	1.12E5 353	3.32E5 1048						7.07E5 2485			1.32E4 41.8		550 1.74				
	FUGITIVE EMISSION	DUST *	10																					
		DIESEL EMISSIONS	11	2000	540	101	1.11E6		560 1.12	1.02E4 20.4	6.66E4 133	7660 15.3	95.8 .192		8.91E5 1782	3.75E4 75	330 .66	1.50E4 30		1.88E4 37.5	5.46E4 109		5110 10.2	2780 5.56
EXTRACTION	HOT WATER EXTRACTION	STEAM VENTS	14	2.27E5	200	101	7.62E5	7.62E5 1.73E5																
	FROTH TREATMENT	VENTS	16	1313		101	1.47E6	7.72E4 106	798 1.1		2.58E5 354				7.62E5 1046			1.76E4 24.2				3.50E5 481		
UPGRADING	SULPHUR PLANT	EMISSIONS	18	3.89E5	538	105	1.20E6	3.98E4 1.55E4	9.30E4 3.62E4			634 247	6.77 2.64		1.06E6 4.14E5	211 82.3								
	UPGRADING HEATERS	FLUE GAS	22	4.81E6	400	110	1.21E6	2.10E4 1.01E5	2.46E5 1.18E6		2.10E4 1.01E5	25 120	.1 .48		8.37E5 4.02E6	270 1297		1.52E4 7.30E4						
UTILITIES	PITCH BOILERS	FLUE GAS	25	1.83E6	171	101	1.27E6	5.09E4 9.30E4	2.50E5 4.57E5		4.49E4 8.22E4	605 1106	8 14.6		8.94E5 1.64E6	872 1594		1.50E4 2.74E4		125 229				
	NG BOILERS	FLUE GAS	28	2.13E6	177	101	1.18E6	1.22E5 2.60E5	1.51E5 3.22E5		4.32E4 9.22E4				8.51E5 1.81E6	263 561		1.43E4 3.05E4	5.51 11.7					
	WASTE HEAT BOILERS	FLUE GAS	29	1.11E7	177	101	1.16E6	1.40E5 1.55E6	1.74E5 1.92E6		2805 3.10E4				8.26E5 9.12E6	23.1 255		1.39E4 1.53E5	6 66.3					
	NG SUPERHEATERS	FLUE GAS	30	3.57E5	177	101	1.18E6	1.32E5 4.71E4	1.63E5 5.82E4		2.33E4 8309				8.44E5 3.01E5	284 101		1.42E4 5062	5.97 2.13					
OFFSITES	FLARE	EMISSIONS	34	4.31E4	1000	101	1.18E6	1.43E5 6146	1.82E5 7855			54 2.33	.7 .03		8.36E5 3.61E4			1.44E4 619						
	SOLID WASTE	INCINERATOR EMIS	44	8890	650	103	1.23E6	1.22E5 1082	3.06E5 2722			122 1.08	1.5 .013		7.99E5 7102	1105 9.82				123 1.09				

* NOT CHARACTERIZED

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.05E8

UNITS AS ABOVE UNLESS NOTED OTHERWISE

Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
		6.40E4 6.25		2.40E4 2.34		4.10E4 4	1.50E4 1.46			8.00E4 7.81				2.10E4 2.05			3.20E5 31.2	8000 .781		
														1.00E6 1.27E5						
		9837 530		2590 139		1730 93.1	315 17			1198 64.5	1605 86.4	134 7.21					5.20E4 2802		1867 101	
		9.92E4 2245								8264 187							5.29E5 1.20E4			

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

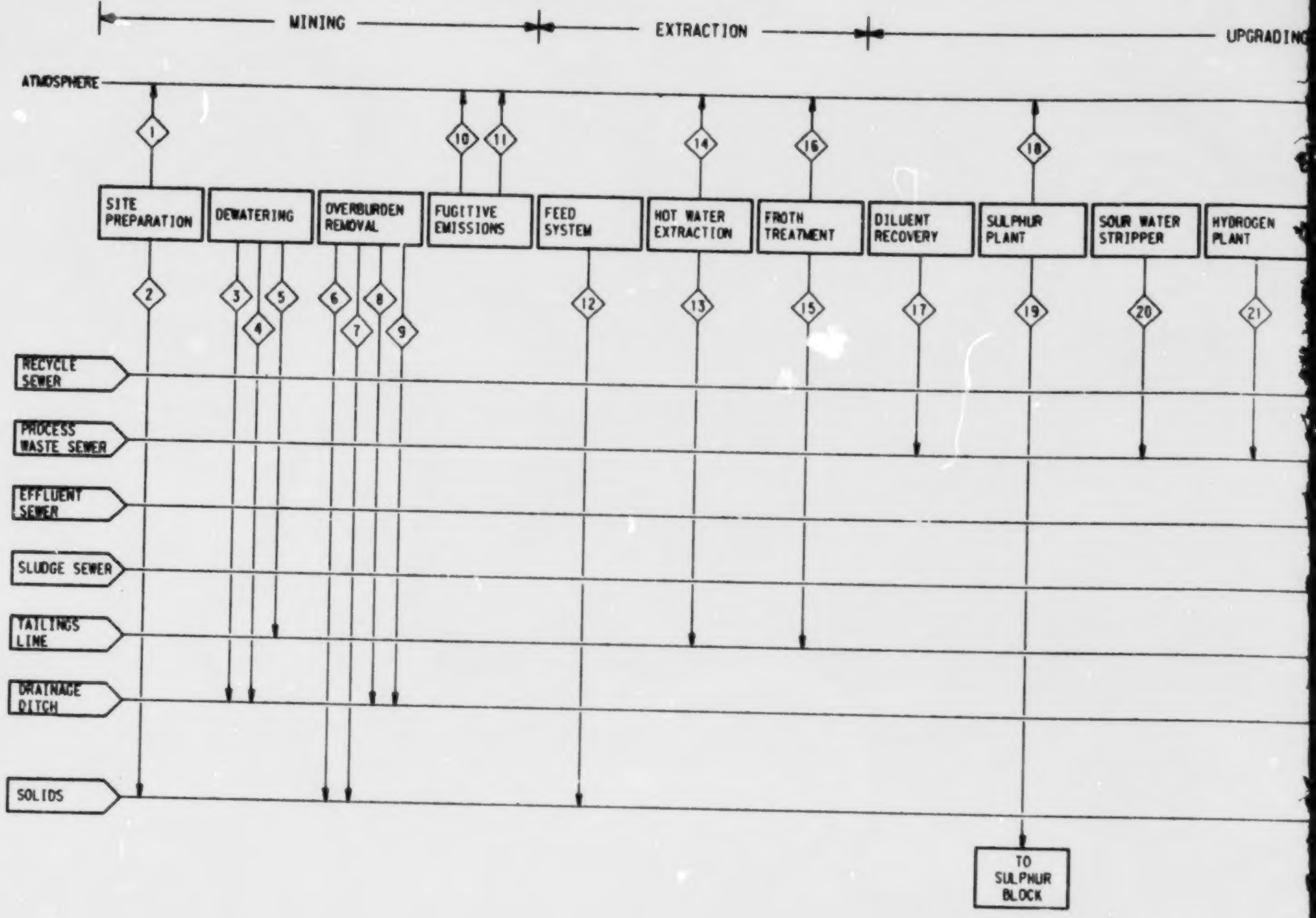
DATA PRESENTATION: GASES

PARAMETER	CO_2
CONCENTRATION mg/m^3	4000
LOADING kg/sd	1.42E6

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

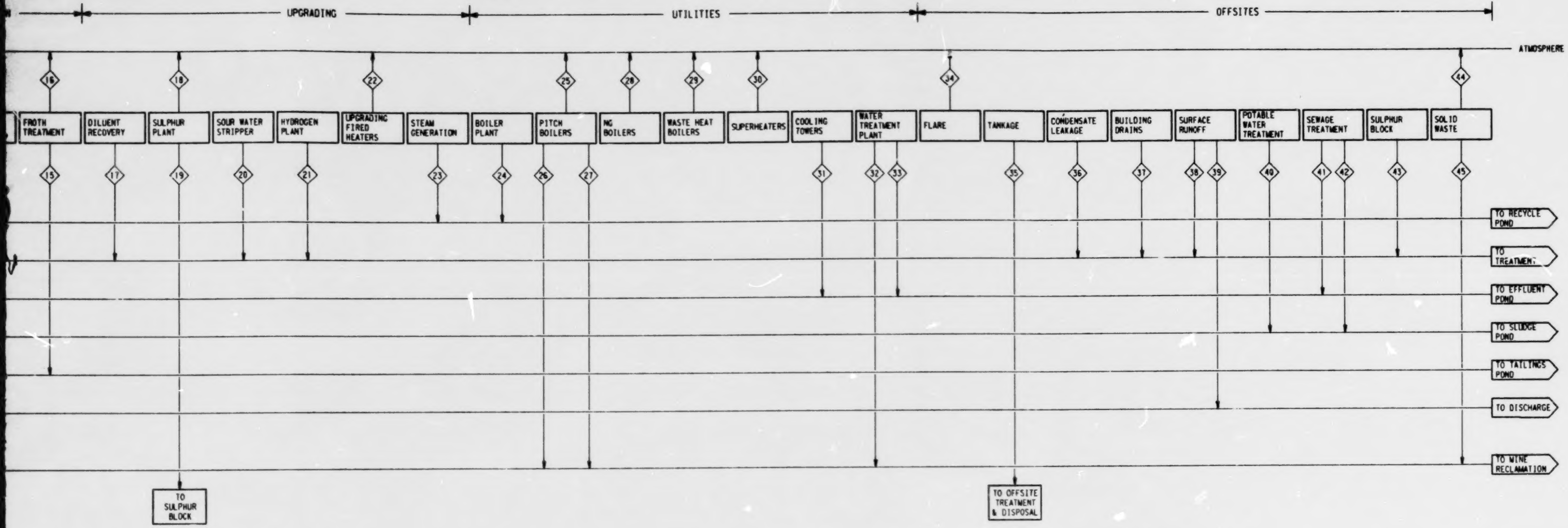
MATRIX 3-26

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION 13 HOT WATER EXTRACTION/CANMET/
PITCH BOILERS (FBC)
MONENCO CONSULTANTS LIMITED


MINING
EXTRACTION
UPGRADING
ATMOSPHERE
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
HOT WATER EXTRACTION
FROTH TREATMENT
DILUENT RECOVERY
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
TAILINGS LINE
DRAINAGE DITCH
SOLIDS
TO SULPHUR BLOCK

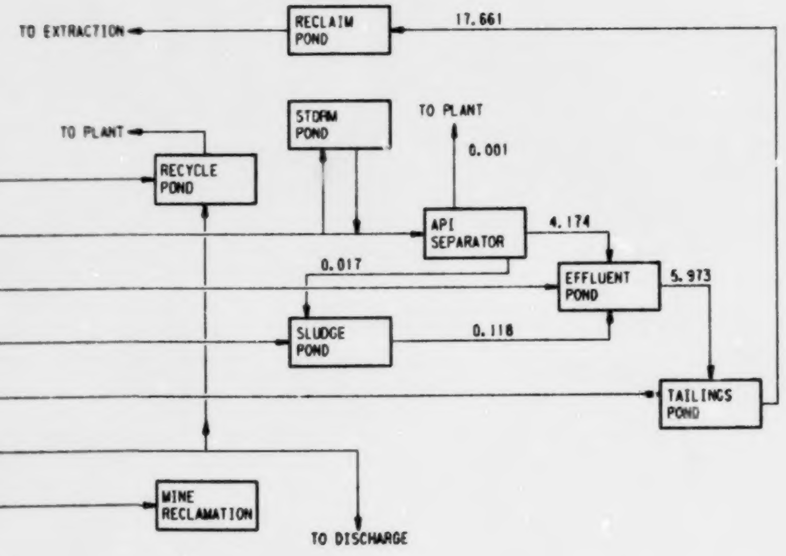
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
ATMOSPHERIC EMISSIONS $10^6 m^3$/sd	0.003									✱	0.002			0.227		0.001		0.389				4.805			1.828	
RECYCLE SEWER $10^3 m^3$/sd																							0.035	0.054		
PROCESS WASTE SEWER $10^3 m^3$/sd																	0.307			0.422	0.512					
EFFLUENT SEWER $10^3 m^3$/sd																										
SLUDGE SEWER $10^3 m^3$/sd																										
TAILINGS LINE $10^3 m^3$/sd					0.678								39.01		2.420											
DRAINAGE DITCH $10^3 m^3$/sd			0.205	1.000				0.563	0																	
SOLIDS t/sd		0.098				3660	20700					1182														53.84
OTHER SOLIDS t/sd																			127.4							
OTHER LIQUIDS $10^3 m^3$/sd																										

✱ NOT QUANTIFIED


UPGRADING
UTILITIES
OFFSITES
ATMOSPHERE
16
18
22
25
28
29
30
34
44
FROTH TREATMENT
DILUENT RECOVERY
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
BOILER PLANT
PITCH BOILERS
NG BOILERS
WASTE HEAT BOILERS
SUPERHEATERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
SULPHUR BLOCK
SOLID WASTE
15
17
19
20
21
23
24
26
27
31
32
33
35
36
37
38
39
40
41
42
43
45
TO RECYCLE POND
TO TREATMENT
TO EFFLUENT POND
TO SLUDGE POND
TO TAILINGS POND
TO DISCHARGE
TO MINE RECLAMATION
TO SULPHUR BLOCK
TO OFFSITE TREATMENT & DISPOSAL

4	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	TOTAL ANNUAL FLOW +	TOTAL FLOW PER SD
27		0.001		0.389				4.805			1.828			2.132	11.05	0.357				0.043										0.009		6.23E9	20.85
									0.035	0.054																						2.70E4	0.089
			0.307			0.422	0.512															0.039	0.654	2.245					0.013			1.10E6	4.192
																	0.720		0.390								0.570					5.32E5	1.680
																										0.030		0.005				1.28E4	0.035
	2.420																															1.22E7	42.11
																									0.490							6.34E5	2.250
												53.84	22.63					5.170													0.831	4.10E6	25625
					127.4																											4.07E4	127.4
																					0.005											1.50E2	0.005

+ UNITS FOR TOTAL ANNUAL FLOW
ATMOSPHERIC EMISSIONS m³/yr
LIQUID STREAMS m³/yr
SOLIDS t/yr


TO EXTRACTION
RECLAIM POND
17.661
TO PLANT
STORM POND
TO PLANT
0.001
RECYCLE POND
API SEPARATOR
4.174
0.017
EFFLUENT POND
5.973
SLUDGE POND
0.118
TAILINGS POND
MINE RECLAMATION
TO DISCHARGE

	WASTE STREAM
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	WET TAILINGS
14	STEAM VENTS
15	WET TAILINGS
16	VENTS
17	WASTEWATER
18	EMISSIONS
19	SULPHUR
20	SWS WASTEWATER
21	CONDENSATE
22	FLUE GAS
23	BLOWDOWN
24	BLOWDOWN
25	FLUE GAS
26	SPENT BED SOLIDS
27	FLY ASH
28	FLUE GAS
29	FLUE GAS
30	FLUE GAS
31	BLOWDOWN
32	SOFTENER SOLIDS
33	REGENERANT WASTE
34	EMISSIONS
35	TANK BOTTOMS
36	CONDENSATE
37	WASHDOWN
38	INPLANT RUNOFF
39	CLEAN RUNOFF
40	ALUM SLUDGE
41	EFFLUENT
42	DIGESTED SLUDGE
43	BLOCK RUNOFF
44	INCINERATOR EMIS
45	NONCOMBUSTIBLES

FIGURE 3-14 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 13 HOT WATER EXTRACTION/CANMET/
PITCH BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

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WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3	TKN	NO_3	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	SOLVENT	OIL & GREASE	PHENOL	DEA	SO_4	SULPHIDES	S_2O_3	PO_4	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al
MINING	DEWATERING	SHALLOW AQUIFER	3	247		1000	7.6						295 72.9						7 1.73			467 115									11 2.72				34 8.4				68 16.8	24 5.93		72 17.8	3 .741	
		BASAL AQUIFER	4	1000		1005	7.4						1440 1440									3778 3778									55 55	23.5 23.5			1060 1060				55 55	30 30		1137 1137		
		MINE WATER	5	818		1000	8.3			12 9.82							.28 .229				6.5 5.32	400 327						3 2.45								.23 .188			99.7 81.6	24.8 20.3	.31 .254	66 54	2.87 2.35	
	OVERBURDEN	MUSKEG RUNOFF	8	465		1000	7.3		34 15.8	8 3.72		64.6 30	78.7 36.6					.35 .163			365 170	10 4.65									.1 .046				1.7 .79	.06 .028			16.5 7.67	4.5 2.09		4.9 2.28	.5 .232	
		SUBSOIL RUNOFF	9	254		1000	7.6				30 7.62										6123 1555	150 38.1													10 2.54				15 3.81	5 1.27		15 3.81		
EXTRACTION	SOLVENT EXTRACTION	WASTEWATER	14	1500	55	1000																		TRACE		TRACE																		
UPGRADING	SOLVENT RECOVERY	WASTEWATER	16	135		1000										TRACE	TRACE											TRACE																
	SOUR WATER STRIPPER	SWS WASTEWATER	21	790	140	1000	8.1		295 233		204 161					5 3.95	50 39.5				10 7.9								12 9.48		33 26.1		150 118		117 92.4		.1 .079	.36 .284	9 7.11					
	HYDROGEN PLANT	CONDENSATE	22	372		1000								TRACE	19 7.07										TRACE																			
	UPGRADING STEAM	BLOWDOWN	24	47	174	1000	9.5															120 5.64													9 .423							14 .658		
UTILITIES	BOILER PLANT	BLOWDOWN	25	85	174	1000	9.5					400 34									150 12.8	2500 213																	500 42.5					
	COOLING TOWER	BLOWDOWN	27	2370	24	1000	7.5				50 119	50 119					10 23.7				160 379	725 1718						10 23.7			290 687			TRACE	30 71.1				170 403	40 94.8	.24 .569	95 225	8 19	1.84 4.36
	WATER T'MENT PLANT	REGENERANT WASTE	29	616		1000	7						145 89.3									6490 3998									3741 2304				481 296				460 283	138 85		1398 861	25 15.4	
OFFSITES	TANKAGE	TANK BOTTOMS	31	6		1100		4.33E5 2756												9.13E4 581								5.75E5 3659																
	CONDENSATE LEAKAGE	CONDENSATE	32	39		1000						400 15.6									1000 38.9	2500 97.3						1000 38.9											150 5.83					
	BUILDING DRAINS	WASHDOWN	33	654		1000	8.1						158 103				.12 .078	1.2 .785	.046 .03		1000 654	200 131						1000 654	3 1.96	270 177	15.1 9.88	32 20.9		1.05 .687	7.7 5.04	.11 .072			41.8 27.3	9 5.89		23.5 15.4	1.7 1.11	
	SURFACE RUNOFF	INPLANT RUNOFF	34	2245		1000	7.6		511 1146	10 22.5	74.1 166	90 202						7.07 15.9	3.17 7.12		1170 2627	350 786						200 449	.025 .056					1.6 3.59	52 117				15 33.7	5 11.2		15 33.7		
		CLEAN RUNOFF	35	490		1000	7.6		511 250		74.1 36.3							7.07 3.46	3.17 1.55		660 323	200 98													26 12.7				15 7.35	5 2.45		15 7.35		
	POTABLE WATER T'MENT	ALUM SLUDGE	36	30		1000		9.70E5 2.91E4													3.00E4 900																							
	SEWAGE TREATMENT	EFFLUENT	37	570		1000					25 14.3										25 14.3							25 14.3																
		DIGESTED SLUDGE	38	5		1022		9.49E5 4327													5.11E4 233																							
	SULPHUR STORAGE	BLOCK RUNOFF	39	14		1000	6														200 2.77												TRACE											

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
34 8.4				68 16.8	24 5.93		72 17.8	3 .741												6 1.48			
1060 1060				55 55	30 30		1137 1137					.9 .9			.5 .5								
	.23 .188			99.7 81.6	24.8 20.3	.31 .254	66 54	2.87 2.35			.19 .155		.004 .003	.007 .006	.85 .695		.021 .017	.011 .009		8.25 6.75	.39 .319		.046 .038
1.7 .79	.06 .028			16.5 7.67	4.5 2.09		4.9 2.28	.5 .232												2.2 1.02			
10 2.54				15 3.81	5 1.27		15 3.81																
117 92.4		.1 .079	.36 .284	9 7.11									.07 .055		8.8 6.95					2.6 2.05			
9 .423							14 .658													6 .282			
				500 42.5																35 2.97			
30 71.1				170 403	40 94.8	.24 .569	95 225	8 19	1.84 4.36		.64 1.52		.032 .076	TRACE	4.9 11.6	.2 .474	.044 .104			36 85.3			
481 296				460 283	138 85		1398 861	25 15.4												103 63.4			
				150 5.83																35 1.36			
7.7 5.04	.11 .072			41.8 27.3	9 5.89		23.5 15.4	1.7 1.11			.16 .105									12 7.85			
52 117				15 33.7	5 11.2		15 33.7												52 117				
26 12.7				15 7.35	5 2.45		15 7.35																

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L	500
LOADING kg/sd	1440

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-27

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 14 SOLVENT EXTRACTION/FLEXICOKING/
FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED

41

AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLA
MINING	SITE PREPARATION	ASH	2	117		400		5000 .587				5.98E4 6.92					
	OVERBURDEN	MUSKEG	6	4.41E6		840	7.6										
		SUBSOIL	7	2.49E7		1600	7.5								6.30E5 1.57E7	2.07E5 5.16E6	1.62E 4.04E
EXTRACTION	FEED SYSTEM	REJECTS	12	1.25E6													
	SOLVENT EXTRACTION	DRY TAILINGS	13	3.35E7	100	1488		1.20E5 4.01E6	4995 1.67E5		1000 3.35E4				8.44E5 2.83E7	8741 2.93E5	2.10E 7.02
UPGRADING	FLEXICOKING	CHAR	17	9.52E4				7.79E4 7415				1.12E5 1.07E4	7.85E5 7.47E4				
		COKE FINES	18	1.50E4		1180		1.00E5 1502					[illegible].00E5 1.35E4				
	SULPHUR PLANT	SULPHUR	20	1.60E5		2046		100 16.8				2 .337					
UTILITIES	WATER T'MENT PLANT	SOFTENER SOLIDS	28	8171		2040		4.00E5 3268									
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	41	831		4700						5.49E5 456					

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DA

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m³	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3
MINING	SITE PREPARATION	EMISSIONS	1	3795	400	101	1.25E6	1.12E5 425	3.32E5 1260						7.87E5 2998		
	FUGITIVE EMISSION	DUST *	10														
		DIESEL EMISSIONS	11	2000	540	101	1.11E6		560 1.12	1.02E4 20.4	6.66E4 133	7660 15.3	95.8 .192		8.91E5 1782	3.75E4 75	330 .66
EXTRACTION	SOLVENT EXTRACTION	VENT GAS	15	1.06E5	38	183	1.21E6	3.05E4 3221	277 29.3		2.72E5 2.87E4				8.07E5 9.38E4		
UPGRADING	SULPHUR PLANT	EMISSIONS	19	5.35E5	538	105	1.25E6	3.68E4 1.97E4	2.25E5 1.20E5			592 317	10.2 5.46		9.83E5 5.26E5	211 113	
	UPGRADING HEATERS	FLUE GAS	23	3.60E6	400	110	1.24E6	9.13E4 3.29E5	2.59E5 9.31E5		4.21E4 1.51E5	170 612	3 10.8		8.30E5 2.99E6	270 972	
UTILITIES	PG BOILERS	FLUE GAS	26	9.99E6	177	101	1.21E6	1.06E5 1.05E6	2.16E5 2.15E6		3.25E4 3.25E5	666 6655	8.43 84.2		8.46E5 8.45E6	212 2118	
OFFSITES	FLARE	EMISSIONS	30	5.19E4	1000	101	1.19E6	1.32E5 6873	1.95E5 1.01E4			600 31.2	8 .415		8.44E5 4.38E4		
	SOLID WASTE	INCINERATOR EMIS	40	8890	650	103	1.23E6	1.22E5 1082	3.06E5 2722			122 1.08	1.5 .013		7.99E5 7102	1105 9.82	

* NOT CHARACTERIZED

MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY	SPENT CA'LYST	TOTAL ORG.	TOTAL INORG.	LIME	$CaCO_3$	$CaSO_4$	METALS	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
5000 .587				5.90E4 6.92														1.10E5 12.9					8.50E5 99.7	2.53E5 29.7				6.40E4 7.51		2.40E4 2.82		4.10E4 4.81	1.50E4 1.76			8.00E4 9.38				2.10E4 2.46			3.20E5 37.5	8000 .938		
											9.76E5 4.30E6	2.40E4 1.06E5																																		
							6.30E5 1.57E7	2.07E5 5.16E6	1.62E5 4.04E6																																					
1.20E5 4.01E6	4995 1.67E5		1000 3.35E4				8.44E5 2.83E7	8741 2.93E5	2.10E4 7.02E5																																					
7.79E4 7415				1.12E5 1.07E4	7.85E5 7.47E4												1.9 .181	6512 620	83 7.9		74 7.04			1520 145	17 1.62	55 5.23	18 1.71	6485 617	4640 442	5074 483		695 66.1	91 8.66	204 19.4	4824 459	891 84.8	1633 155	174 16.6	6 .571	1.51E4 1439				1985 189	7430 707	31 2.95
1.00E5 1502					9.00E5 1.35E4																																									
100 16.8				2 .337																			15 2.53																	1.00E6 1.68E5						
4.00E5 3268														6.00E5 4903																																
				5.49E5 456												4.51E5 375																														

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
1.12E5 425	3.32E5 1260						7.87E5 2988			1.32E4 50.2		550 2.09				
	560 1.12	1.02E4 20.4	6.66E4 133	7660 15.3	95.8 .192		8.91E5 1782	3.75E4 75	330 .66	1.50E4 30		1.88E4 37.5	5.46E4 109		5110 10.2	2780 5.56
3.05E4 3221	277 29.3		2.72E5 2.87E4				8.97E5 9.38E4			1.49E4 1571						
3.68E4 1.97E4	2.25E5 1.20E5			592 317	10.2 5.46		9.83E5 5.26E5	211 113								
9.13E4 3.29E5	2.59E5 9.31E5		4.21E4 1.51E5	170 612	3 10.8		8.30E5 2.99E6	270 972		1.52E4 5.47E4						
1.06E5 1.05E6	2.16E5 2.15E6		3.25E4 3.25E5	666 6655	8.43 84.2		8.46E5 8.45E6	212 2118		1.07E4 1.07E5	2.58 25.8					
1.32E5 6873	1.95E5 1.01E4			600 31.2	8 .415		8.44E5 4.38E4			1.42E4 735						
1.72E5 1082	3.06E5 2722			122 1.08	1.5 .013		7.99E5 7102	1105 9.82				123 1.09				

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

DATA PRESENTATION: GASES

PARAMETER	CO_2
CONCENTRATION mg/m^3	4000
LOADING kg/sd	1.42E6

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

MATRIX 3-28

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 14 SOLVENT EXTRACTION/FLEXICOKING/
FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED

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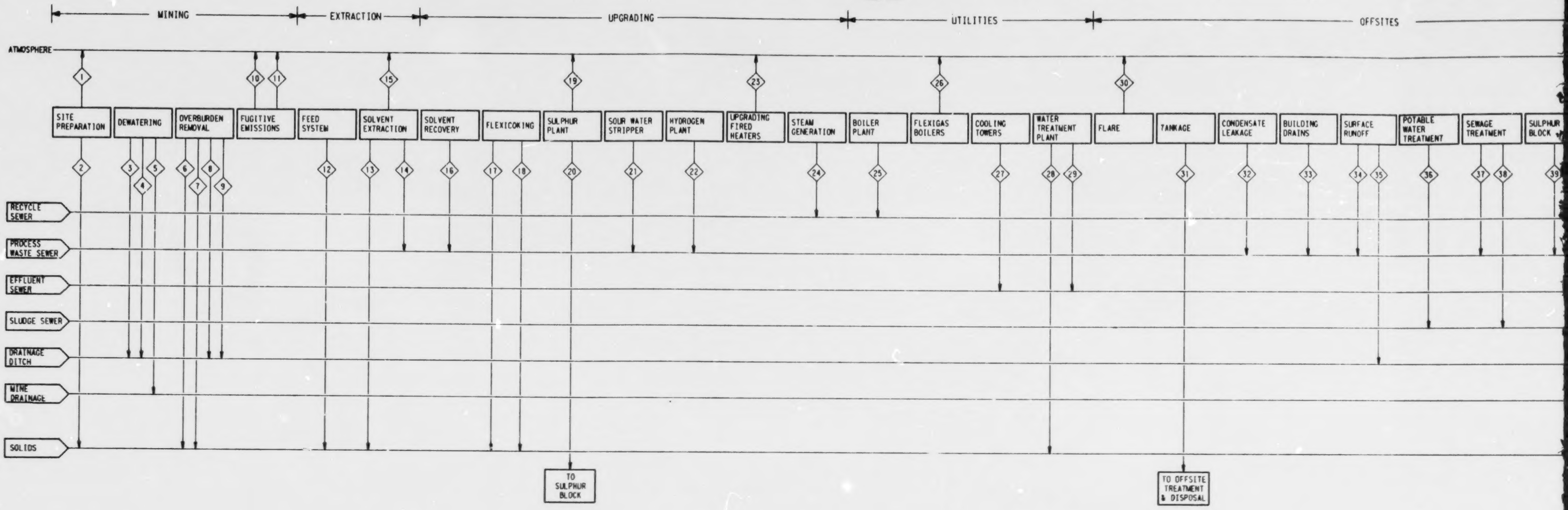
MONENCO CONSULTANTS LIMITED


MINING
EXTRACTION
UPGRADING
UTILITIES
OFFSITES
ATMOSPHERE
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
SOLVENT EXTRACTION
SOLVENT RECOVERY
FLEXICOKING
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
BOILER PLANT
FLEXIGAS BOILERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
SULPHUR BLOCK
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
DRAINAGE DITCH
MINE DRAINAGE
SOLIDS
TO SULPHUR BLOCK
TO OFFSITE TREATMENT & DISPOSAL
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
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19
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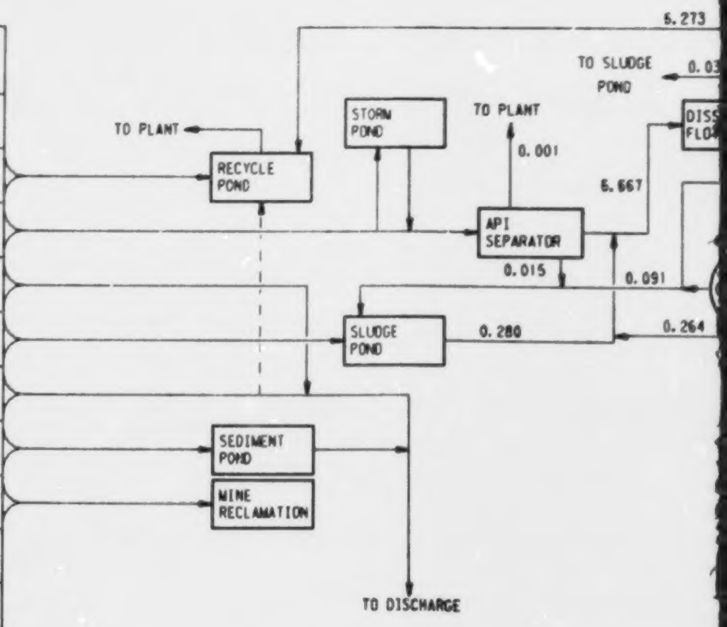
37
38
39

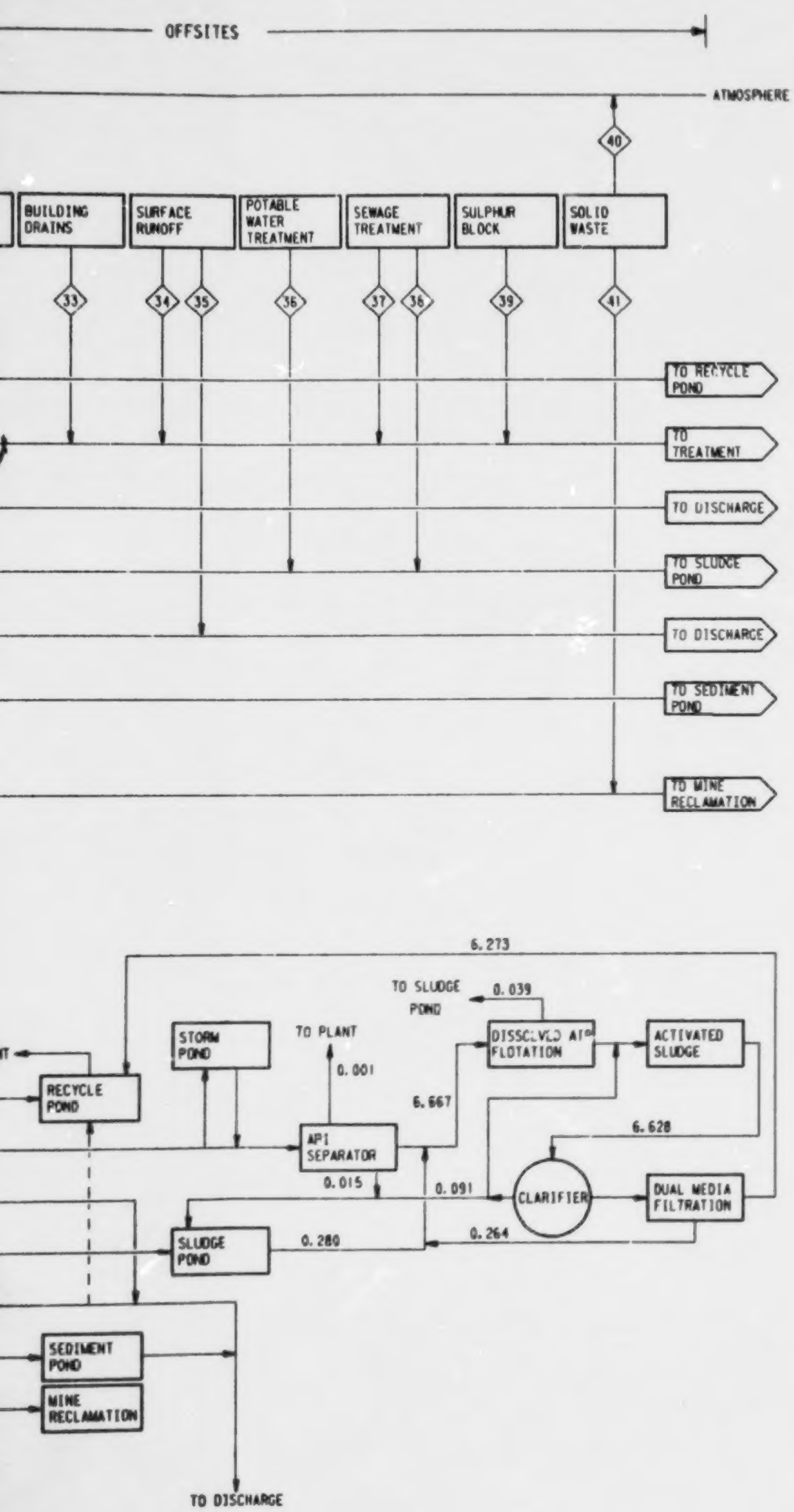
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
ATMOSPHERIC EMISSIONS $10^6 m^3/sd$	0.003									⁎	0.002				0.106				0.535		
RECYCLE SEWER $10^3 m^3/sd$																					
PROCESS WASTE SEWER $10^3 m^3/sd$														1.500		0.135					0.790
EFFLUENT SEWER $10^3 m^3/sd$																					
SLUDGE SEWER $10^3 m^3/sd$																					
DRAINAGE DITCH $10^3 m^3/sd$			0.247	1.000				0.465	0.254												
MINE DRAINAGE $10^3 m^3/sd$					0.818																
SOLIDS t/sd		0.117				4410	24900					1248	33478				95.16	15.02			
OTHER SOLIDS t/sd																				168.5	
OTHER LIQUIDS $10^3 m^3/sd$																					

	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	TOTAL ANNUAL FLOW +	TOTAL FLOW PER SD
ATMOSPHERIC EMISSIONS $10^6 m^3/sd$		3.600			9.990				0.052										0.009		4.29E9	14.30
RECYCLE SEWER $10^3 m^3/sd$			0.047	0.085																	3.98E4	0.132
PROCESS WASTE SEWER $10^3 m^3/sd$	0.372										0.039	0.654	2.245			0.570		0.014			1.76E6	6.319
EFFLUENT SEWER $10^3 m^3/sd$						2.370		0.616													9.82E5	2.986
SLUDGE SEWER $10^3 m^3/sd$															0.030		0.005				1.28E4	0.035
DRAINAGE DITCH $10^3 m^3/sd$														0.490							6.76E5	2.456
MINE DRAINAGE $10^3 m^3/sd$																					1.39E5	0.818
SOLIDS t/sd							8.171													0.831	1.47E7	64155
OTHER SOLIDS t/sd																					5.38E4	168.5
OTHER LIQUIDS $10^3 m^3/sd$										0.006											1.82E2	0.006


6.273
TO SLUDGE POND
0.03
TO PLANT
RECYCLE POND
STORM POND
TO PLANT
0.001
DISS FLO
6.667
API SEPARATOR
0.015
0.091
SLUDGE POND
0.280
0.264
SEDIMENT POND
MINE RECLAMATION
TO DISCHARGE

⁎ NOT QUANTIFIED

+ UNITS FOR TOTAL ANNUAL FLOW: ATMOSPHERIC EMISSIONS m^3/yr
LIQUID STREAMS m^3/yr
SOLIDS t/yr


OFFSITES
ATMOSPHERE
40
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
SULPHUR BLOCK
SOLID WASTE
33
34
35
36
37
38
39
41
TO RECYCLE POND
TO TREATMENT
TO DISCHARGE
TO SLUDGE POND
TO DISCHARGE
TO SEDIMENT POND
TO MINE RECLAMATION
6.273
TO SLUDGE POND
0.039
STORM POND
TO PLANT
0.001
DISSOLVED AIR FLOTATION
ACTIVATED SLUDGE
RECYCLE POND
6.667
6.628
API SEPARATOR
0.015
0.091
CLARIFIER
DUAL MEDIA FILTRATION
SLUDGE POND
0.280
0.264
SEDIMENT POND
MINE RECLAMATION
TO DISCHARGE

◇	WASTE STREAM
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	DRY TAILINGS
14	WASTEWATER
15	VENT GAS
16	WASTEWATER
17	CHAR
18	COKE FINES
19	EMISSIONS
20	SULPHUR
21	SWS WASTEWATER
22	CONDENSATE
23	FLUE GAS
24	BLOWDOWN
25	BLOWDOWN
26	FLUE GAS
27	BLOWDOWN
28	SOFTENER SOLIDS
29	REGENERANT WASTE
30	EMISSIONS
31	TANK BOTTOMS
32	CONDENSATE
33	WASHDOWN
34	INPLANT RUNOFF
35	CLEAN RUNOFF
36	ALUM SLUDGE
37	EFFLUENT
38	DIGESTED SLUDGE
39	BLOCK RUNOFF
40	INCINERATOR EMIS
41	NONCOMBUSTIBLES

FIGURE 3-15 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 14 SOLVENT EXTRACTION/FLEXICOKING/
FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED

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AREA	PROCESS	WASTE STREAM	◇	FLOW m^3/sd	TEMP. °C	DENSITY kg/m^3	pH	H_2O	COD	TOC	BOD_5	TOTAL ALK.	HCO_3	H_2	CO_2	H_2S	NH_3.	TKN
MINING	DEWATERING	SHALLOW AQUIFER	3	230		1000	7.6						295 67.8					
		BASAL AQUIFER	4	1000		1005	7.4						1440 1440					
		MINE WATER	5	758		1000	8.3			12 9.1							.28 .212	
	OVERBURDEN	MUSKEG RUNOFF	8	461		1000	7.3		34 15.7	8 3.69		64.6 29.8	78.7 36.3					.35 .161
		SUBSOIL RUNOFF	9	228		1000	7.6				30 6.84							
EXTRACTION	DIRECT COKING	WASTEWATER	15	1515	49	1000	6.5									2 3.03	32 48.5	
		BLOWDOWN	16	117	174	1000	9.5					400 46.9						
UPGRADING	SOUR WATER STRIPPER	SWS WASTEWATER	20	235	140	1000	8.1		295 69.2		204 47.9					5 1.17	50 11.7	
	HYDROGEN PLANT	CONDENSATE	21	346		1000								TRACE	19 6.57			
	UPGRADING STEAM	BLOWDOWN	23	20	174	1000	9.5											
UTILITIES	COOLING TOWER	BLOWDOWN	25	2530	24	1000	7.5				50 127	50 127					10 25.3	
	WATER T'MENT PLANT	REGENERANT WASTE	27	681		1000	7						145 98.7					
OFFSITES	TANKAGE	TANK BOTTOMS	29	8		1100		4.33E5 3307										
	CONDENSATE LEAKAGE	CONDENSATE	30	39		1000						400 15.6						
	BUILDING DRAINS	WASHDOWN	31	523		1000	8.1						158 82.6				.12 .063	1.2 .628
	SURFACE RUNOFF	INPLANT RUNOFF	32	1633		1000	7.6		511 834	10 16.3	74.1 121	90 147						7.07 11.5
		CLEAN RUNOFF	33	490		1000	7.6		511 250		74.1 36.3							7.07 3.46
	POTABLE WATER T'MENT	ALUM SLUDGE	34	30		1000		9.70E5 2.91E4										
	SEWAGE TREATMENT	EFFLUENT	35	570		1000					25 14.3							
		DIGESTED SLUDGE	36	5		1022		9.49E5 4327										
	SULPHUR STORAGE	BLOCK RUNOFF	37	11		1000	6											

MONENCO CONSULTANTS LIMITED

WASTE MANAGEMENT MATRIX-LIQUID WASTE STREAMS (STREAM DAY BASIS)

COD	TOC	BOD$_5$	TOTAL ALK.	HCO$_3$	H$_2$	CO$_2$	H$_2$S	NH$_3$	TKN	NO$_3$	ASH	TSS	TDS	SAND	BITUMEN	HC	NAPHTHA	FATTY ACIDS	OIL & GREASE	PHENOL	DEA	SO$_4$	SULPHIDES	S$_2$O$_3$	PO$_4$	Cl	F	CN	SCN	Ca	Mg	Mn	Na	K	Al	As	B	Ba	Cu	Cr	Fe	Hg	Ni	Ti	Pb	Si	Sr	V	Zn
				295 67.8						7 1.61			467 107									11 2.53				34 7.81				68 15.6	24 5.51		72 16.5	3 .689												6 1.38			
				1440 1440									3778 3778									55 55	23.5 23.5			1060 1060				55 55	30 30		1137 1137					.9 .9			.5 .5									
	12 9.1							.28 .212				6.5 4.93	400 303						3 2.27								.23 .174			99.7 75.6	24.8 18.8	.31 .235	66 50	2.87 2.18			.19 .144		.004 .003	.007 .005	.85 .644		.021 .016	.011 .008		8.25 6.25	.39 .296		.046 .035
34 15.7	8 3.69		64.6 29.8	78.7 36.3					.35 .161			365 168	10 4.61									.1 .046				1.7 .783	.06 .028			16.5 7.6	4.5 2.07		4.9 2.26	.5 .23												2.2 1.01			
		30 6.84										6123 1395	150 34.2													10 2.28				15 3.42	5 1.14		15 3.42																
							2 3.03	32 48.5										3000 4545		900 1364																													
			400 46.8									150 17.6	2500 293																	500 58.5																35 4.1			
295 69.2		204 47.9					5 1.17	50 11.7				10 2.35								12 2.82		33 7.75		150 35.2		117 27.5		.1 .023	.36 .084	9 2.11									.07 .016		8.8 2.07					2.6 .61			
					TRACE	19 6.57										TRACE																																	
													120 2.4													9 .18							14 .28													6 .12			
		50 127	50 127					10 25.3				160 405	725 1834						10 25.3			290 734			TRACE	30 75.9				170 430	40 101	.24 .607	95 240	8 20.2	1.84 4.66		.64 1.62		.032 .081	TRACE	4.9 12.4	.2 .506	.044 .111			36 91.1			
				145 98.7									6490 4420									3741 2548				481 328				460 313	138 94		1398 952	25 17												103 70.1			
											9.13E4 697								5.75E5 4390																														
			400 15.6									1000 38.9	2500 97.3						1000 38.9											150 5.83																35 1.36			
				158 82.6				.12 .063	1.2 .628	.046 .024		1000 523	200 105						1000 523	3 1.57	270 141	15.1 7.9	32 16.7		1.05 .549	7.7 4.03	.11 .058			41.8 21.9	9 4.71		23.5 12.3	1.7 .889			.16 .084									12 6.28			
511 834	10 16.3	74.1 121	90 147						7.07 11.5	3.17 5.18		1170 1911	350 572						200 327	.025 .041					1.6 2.61	52 84.9				15 24.5	5 8.16		15 24.5												52 84.9				
511 250		74.1 36.3							7.07 3.46	3.17 1.55		660 323	200 98													26 12.7				15 7.35	5 2.45		15 7.35																
												3.00E4 900																																					
		25 14.3										25 14.3							25 14.3																														
												5.11E4 233																																					
												200 2.15												TRACE																									

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: LIQUIDS

PARAMETER	TSS
CONCENTRATION mg/L	500
LOADING kg/sd	1440

UNITS AS ABOVE UNLESS NOTED OTHERWISE

MATRIX 3-29

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 15 DIRECT COKING

MONENCO CONSULTANTS LIMITED

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WASTE MANAGEMENT MATRIX-SOLID WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW kg/sd	TEMP. °C	DENSITY kg/m³	pH	H_2O	BITUMEN	NAPHTHA	SOLVENT	ASH	COKE	PITCH	SAND	SILT	CLAY	SPENT CA'LYST	TOTAL ORG.	TOTAL INORG.
MINING	SITE PREPARATION	ASH	2	189		400		5000 .544				5.90E4 6.42								
	OVERBURDEN	MUSKEG	6	4.09E6		840	7.6												9.76E5 3.99E6	2.40E4 9.82E4
		SUBSOIL	7	2.31E7		1600	7.5								6.30E5 1.46E7	2.07E5 4.79E6	1.62E5 3.75E6			
EXTRACTION	FEED SYSTEM	REJECTS	12	9.84E5		1404	8.5	1.00E5 9.84E4	2.00E4 1.97E4						8.50E5 8.36E5	8799 8655	2.11E4 2.08E4			
	DIRECT COKING	SPENT SAND	13	2.84E7		1600		5.00E4 1.42E6							9.2[illegible]5 2.62E7					
UPGRADING	SULPHUR PLANT	SULPHUR	19	6.68E4		2046		100 6.68				2 .134								
UTILITIES	WATER T'MENT PLANT	SOFTENER SOLIDS	26	9027		2040		4.00E5 3611												
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	39	831		4700						5.49E5 456								

AREA	PROCESS	WASTE STREAM	◇	LIME	$CaCO_3$	$CaSO_4$	METALS	Ag	Al	As	B	Ba	Be	C	Ca	Co	Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo
MINING	SITE PREPARATION	ASH	2						1.10E5 12					8.50E5 92.5	2.53E5 27.5				6.40E4 6.96		2.40E4 2.61		4.10E4 4.46	1.50E4 1.63	
	OVERBURDEN	MUSKEG	6																						
		SUBSOIL	7																						
EXTRACTION	FEED SYSTEM	REJECTS	12																						
	DIRECT COKING	SPENT SAND	13	1.19E4 3.40E5		1.53E4 4.35E5								971 2.76E4											
UPGRADING	SULPHUR PLANT	SULPHUR	19											15 1											
UTILITIES	WATER T'MENT PLANT	SOFTENER SOLIDS	26		6.00E5 5416																				
OFFSITES	SOLID WASTE	NONCOMBUSTIBLES	39				4.51E5 375																		

WASTE MANAGEMENT MATRIX-GASEOUS WASTE STREAMS (STREAM DAY BASIS)

AREA	PROCESS	WASTE STREAM	◇	FLOW m³/sd	TEMP. °C	PRESS. kPa	DENSITY mg/m³	H_2O	CO_2	CO	O_2	SO_2	SO_3	COS	N_2	NOx	NH_3	Ar	He	PARTICULATES	HC	NAPHTHA	ORGANIC ACIDS	ALDEHYDES
MINING	SITE PREPARATION	EMISSIONS	1	3120	400	101	1.25E6	1.12E5 349	3.32E5 1036						7.87E5 2456			1.32E4 41.3		550 1.72				
	FUGITIVE EMISSION	DUST *	10																					
		DIESEL EMISSIONS	11	2000	540	101	1.11E6		560 1.12	1.02E4 20.4	6.66E4 133	7660 15.3	95.8 .192		8.91E5 1782	3.75E4 75	330 .66	1.50E4 30		1.88E4 37.5	5.46E4 109		5110 10.2	2780 5.56
EXTRACTION	DIRECT COKING	FLUE GAS	14	2.15E7	240	101	1.18E6	1.18E5 2.54E6	1.25E5 2.68E6		1.10E5 2.36E6	471 1.01E4			8.25E5 1.78E7	118 2539				115 2475				
	CALCINATING PLANT	FLUE GAS	17	2.87E5	140	101	1.42E6	6.47E4 1.86E4	7.44E5 2.14E5		3.11E4 8935				5.82E5 1.67E5					135 38.8				
UPGRADING	SULPHUR PLANT	EMISSIONS	18	2.10E5	538	105	1.20E6	3.98E4 8377	9.30E4 1.96E4			634 133	6.77 1.42		1.06E6 2.23E5	211 44.5								
	UPGRADING HEATERS	FLUE GAS	22	2.97E6	400	110	1.23E6	9.13E4 2.71E5	2.44E5 7.24E5		4.26E4 1.27E5	16 47.6	.3 .892		8.38E5 2.49E6	270 803		1.52E4 4.52E4						
UTILITIES	NG SUPERHEATERS	FLUE GAS	24	2.91E5	177	101	1.18E6	1.32E5 3.85E4	1.63E5 4.76E4		2.33E4 6783				8.44E5 2.46E5	284 82.7		1.42E4 4132	5.97 1.74					
OFFSITES	FLARE	EMISSIONS	28	5.19E4	1000	101	1.19E6	1.32E5 6873	1.95E5 1.01E4			600 31.2	8 .415		8.44E5 4.38E4			1.42E4 735						
	SOLID WASTE	INCINERATOR EMIS	38	8890	650	103	1.23E6	1.22E5 1082	3.06E5 2722			122 1.08	1.5 .013		7.99E5 7102	1105 9.82				123 1.09				

* NOT CHARACTERIZED

◇ WASTE STREAM NUMBER ON POLLUTANT FLOW DIAGRAM

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS NOTED OTHERWISE

Cr	Cu	Fe	H_2	K	O_2	Mg	Mn	Mo	N_2	Na	Ni	P	Pb	S	Sb	Se	Si	Ti	V	Zn
		6.40E4 6.96		2.40E4 2.61		4.10E4 4.46	1.50E4 1.63			8.00E4 8.7				2.10E4 2.28			3.20E5 34.8	8000 .87		
														1.00E6 6.60E4						

DATA PRESENTATION: SOLIDS

PARAMETER	SAND
CONCENTRATION mg/kg	6.00E5
LOADING kg/sd	4.85E8

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

DATA PRESENTATION: GASES

PARAMETER	CO_2
CONCENTRATION mg/m³	4000
LOADING kg/sd	1.42E6

UNITS AS ABOVE UNLESS
NOTED OTHERWISE

MATRIX 3-30

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 15 DIRECT COKING

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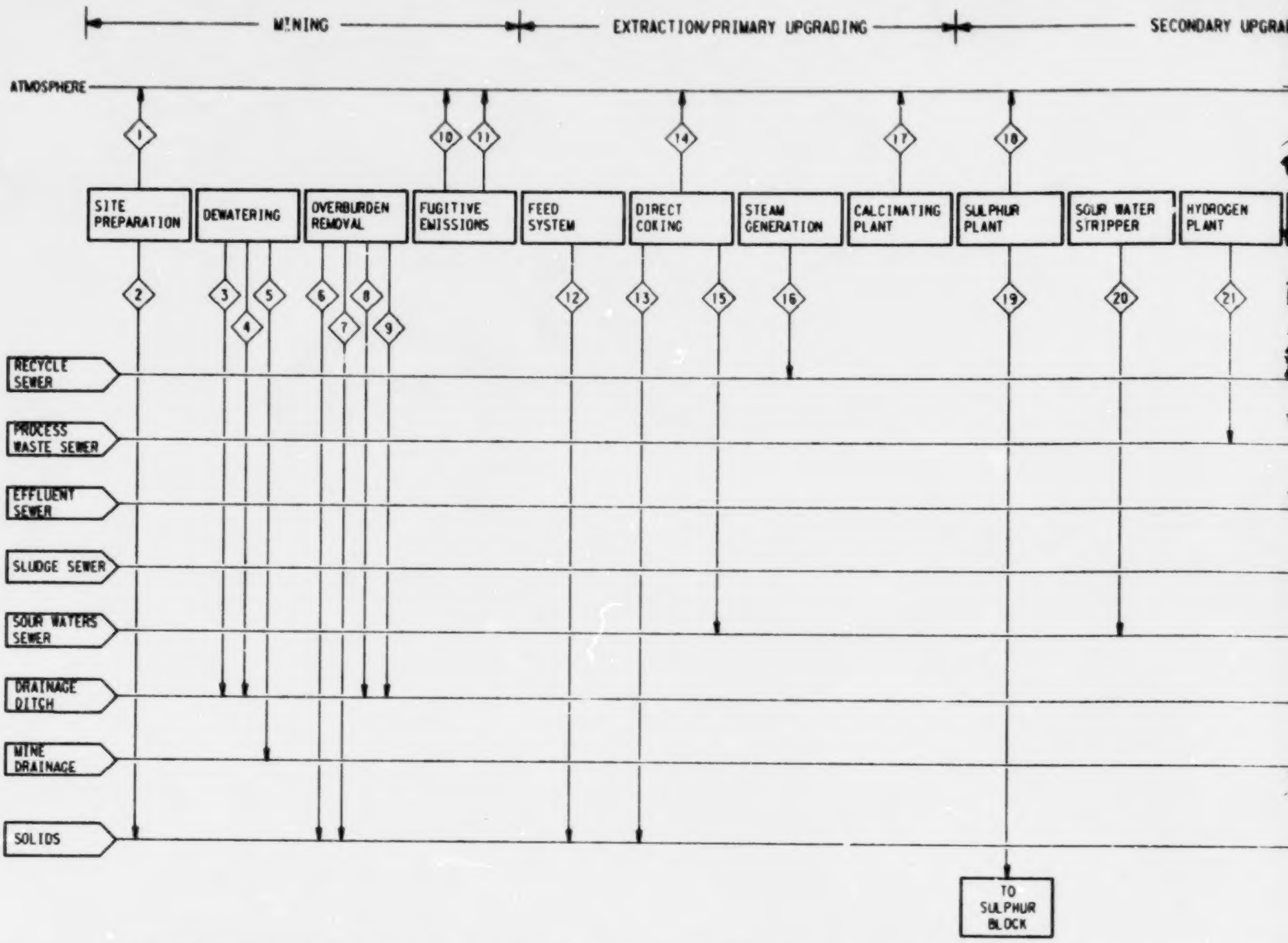
MINING
EXTRACTION/PRIMARY UPGRADING
SECONDARY UPGRA
ATMOSPHERE
SITE PREPARATION
DEWATERING
OVERBURDEN REMOVAL
FUGITIVE EMISSIONS
FEED SYSTEM
DIRECT COKING
STEAM GENERATION
CALCINATING PLANT
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
RECYCLE SEWER
PROCESS WASTE SEWER
EFFLUENT SEWER
SLUDGE SEWER
SOUR WATERS SEWER
DRAINAGE DITCH
MINE DRAINAGE
SOLIDS
TO SULPHUR BLOCK

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
ATMOSPHERIC EMISSIONS $10^6 m^3$/sd	0.003									✱	0.002			21.52			0.287	0.105				2.974		0.291		
RECYCLE SEWER $10^3 m^3$/sd																0.117							0.020			
PROCESS WASTE SEWER $10^3 m^3$/sd																					0.346					
EFFLUENT SEWER $10^3 m^3$/sd																									2.530	
SLUDGE SEWER $10^3 m^3$/sd																										
SOUR WATER SEWER $10^3 m^3$/sd															1.515					0.235						
DRAINAGE DITCH $10^3 m^3$/sd			0.230	1.000				0.461	0.228																	
MINE DRAINAGE $10^3 m^3$/sd					0.758																					
SOLIDS t/sd		0.109				4090	23100					983.6	28430													9.027
OTHER SOLIDS t/sd																			66.8							
OTHER LIQUIDS $10^3 m^3$/sd																										

✱ NOT QUANTIFIED

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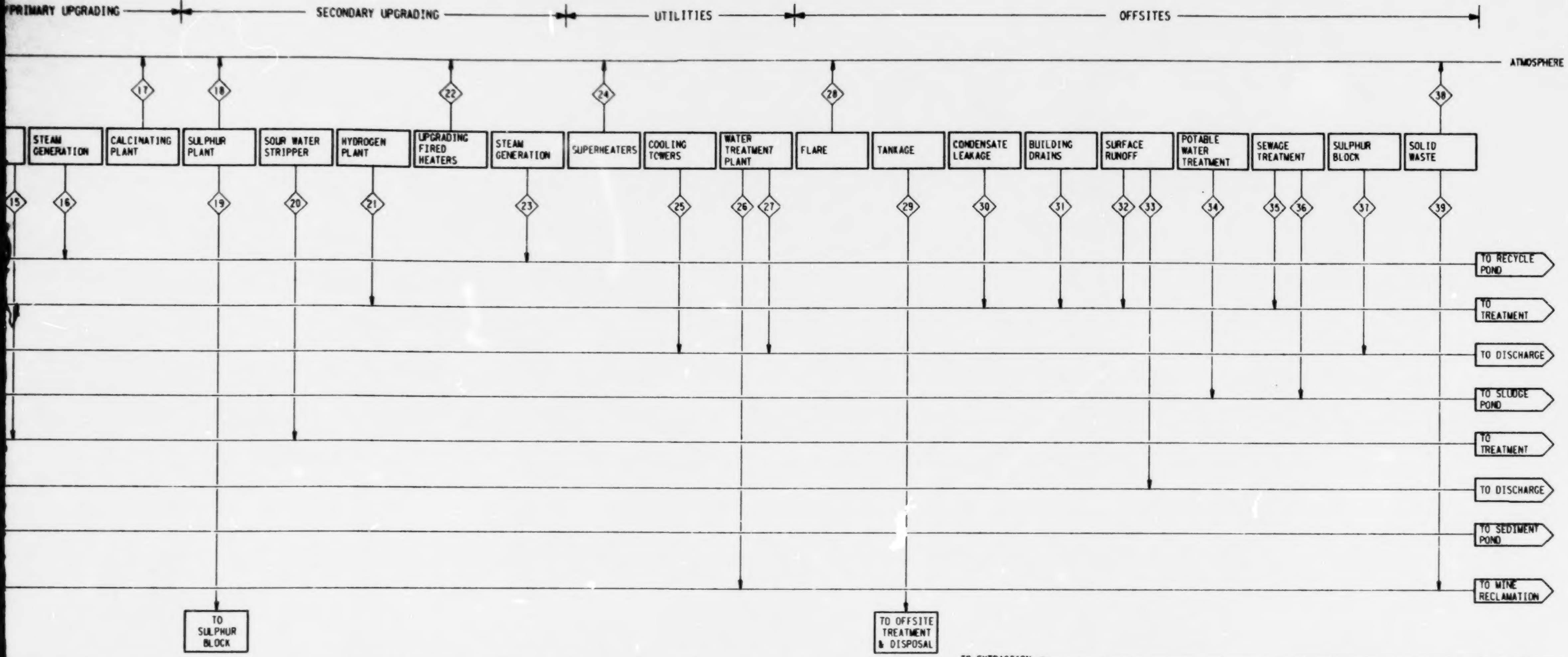
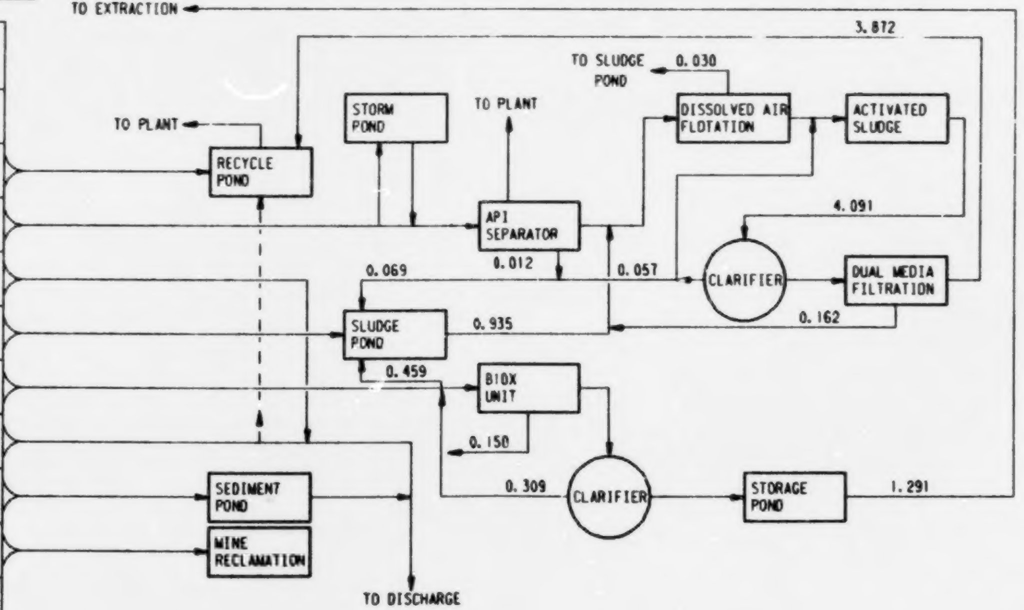

PRIMARY UPGRADING
SECONDARY UPGRADING
UTILITIES
OFFSITES
ATMOSPHERE
STEAM GENERATION
CALCINATING PLANT
SULPHUR PLANT
SOUR WATER STRIPPER
HYDROGEN PLANT
UPGRADING FIRED HEATERS
STEAM GENERATION
SUPERHEATERS
COOLING TOWERS
WATER TREATMENT PLANT
FLARE
TANKAGE
CONDENSATE LEAKAGE
BUILDING DRAINS
SURFACE RUNOFF
POTABLE WATER TREATMENT
SEWAGE TREATMENT
SULPHUR BLOCK
SOLID WASTE
17
18
22
24
28
38
15
16
19
20
21
23
25
26
27
29
30
31
32
33
34
35
36
37
39
TO RECYCLE POND
TO TREATMENT
TO DISCHARGE
TO SLUDGE POND
TO TREATMENT
TO DISCHARGE
TO SEDIMENT POND
TO MINE RECLAMATION
TO SULPHUR BLOCK
TO OFFSITE TREATMENT & DISPOSAL

14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	TOTAL+ ANNUAL FLOW	TOTAL FLOW PER SD
52			0.287	0.105				2.974		0.291				0.052										0.009		7.77E9	25.24
		0.117							0.020																	4.23E4	0.137
							0.346									0.039	0.523	1.633			0.570		0.011			8.50E5	3.122
											2.530		0.681													9.38E5	3.211
																				0.030		0.005				1.28E4	0.035
	1.515					0.235																				5.40E5	1.750
																			0.490							6.66E5	2.409
																										1.29E5	0.758
												9.027													0.831	1.32E7	56614
					66.8																					2.13E4	66.8
															0.008											3.21E2	0.008

+ UNITS FOR TOTAL ANNUAL FLOW: ATMOSPHERIC EMISSIONS m³/yr
LIQUID STREAMS m³/yr
SOLIDS t/yr


TO EXTRACTION
3.872
TO SLUDGE POND
0.030
TO PLANT
STORM POND
TO PLANT
DISSOLVED AIR FLOTATION
ACTIVATED SLUDGE
RECYCLE POND
API SEPARATOR
4.091
0.069
0.012
0.057
CLARIFIER
DUAL MEDIA FILTRATION
SLUDGE POND
0.935
0.162
0.459
BIOX UNIT
0.150
0.309
CLARIFIER
STORAGE POND
1.291
SEDIMENT POND
MINE RECLAMATION
TO DISCHARGE

◇	WASTE STREAM
1	EMISSIONS
2	ASH
3	SHALLOW AQUIFER
4	BASAL AQUIFER
5	MINE WATER
6	MUSKEG
7	SUBSOIL
8	MUSKEG RUNOFF
9	SUBSOIL RUNOFF
10	DUST
11	DIESEL EMISSIONS
12	REJECTS
13	SPENT SAND
14	FLUE GAS
15	WASTEWATER
16	BLOWDOWN
17	FLUE GAS
18	EMISSIONS
19	SULPHUR
20	SWS WASTEWATER
21	CONDENSATE
22	FLUE GAS
23	BLOWDOWN
24	FLUE GAS
25	BLOWDOWN
26	SOFTENER SOLIDS
27	REGENERANT WASTE
28	EMISSIONS
29	TANK BOTTOMS
30	CONDENSATE
31	WASHDOWN
32	INPLANT RUNOFF
33	CLEAN RUNOFF
34	ALUM SLUDGE
35	EFFLUENT
36	DIGESTED SLUDGE
37	BLOCK RUNOFF
38	INCINERATOR EMIS
39	NONCOMBUSTIBLES

FIGURE 3-16 POLLUTANT FLOW DIAGRAM

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 15 DIRECT COKING

MONENCO CONSULTANTS LIMITED

M00130.PFD F24

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PART 4

WASTE MANAGEMENT

PART 4 - WASTE MANAGEMENT

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4.1 INTRODUCTION

The gaseous, liquid and solid waste emissions from the 15 optional oil sands complexes are identified and characterized in Part 3. The collection, handling, treatment, reuse and disposal of the identified waste streams are described here in Part 4. This section summarizes the environmental regulatory aspects likely to govern development of future oil sands facilities.

The development of an oil sands complex will be subject to a number of regulatory approvals and guidelines. The applicable legislation within the Province of Alberta includes:

The Clean Air Act;
The Clean Water Act;
The Water Resources Act;
The Oil and Gas Conservation Act; and
The Land Surface Conservation and Reclamation Act.

The most comprehensive requirements are contained within the Clean Air Act, The Clean Water Act and The Water Resources Act. The Clean Air Act governs overall plant approval relative to all processes causing the release of contaminants or odours to the atmosphere. All raw water or wastewater treatment facilities as well as facilities generating liquid wastes are covered under The Clean Water Act. The Water Resources Act covers permitting of activities relating to groundwater, ground or surface water diversion, and geotechnical investigations.

Regulations under The Clean Air Act set standards for both point source emissions and ambient air quality. In addition to the existing legislation, an oil sands complex may also be subject to future point source emission standards.

The regulations under The Clean Water Act set wastewater discharge requirements for the control of water pollution. In addition, surface water quality guidelines for a number of constituents have been established under the Albert Surface Water Quality Objectives. While specific wastewater discharge guidelines have been developed for both petroleum refineries (Waste Water Effluent Guidelines for Alberta Petroleum Refineries) and gas processing plants (Gas Processing Plants, Waste Water Management Standards), these guidelines may not be directly applicable to an oil sands complex.

In addition to the above acts and regulations pertaining to various Alberta permit and licence requirements, an environmental impact assessment as well as a development and reclamation plan is required for Alberta government review under The Land Surface Conservation and Reclamation Act. The requirement for an industrial development permit is made under The Oil and Gas Conservation Act which is administered by the Energy Resources Conservation Board. Both of these regulatory requirements must be satisfied before the project receives Alberta government approval and can proceed to the permit and licence review phase during which time, applications for specific approvals are made under the appropriate legislation.

Under the British North America Act of 1867, the Federal Government shares responsibilities with the provinces in some areas of environmental protection. This has resulted in the Federal Government establishing minimum point source air and wastewater emission regulations and guidelines for various industrial sectors under the Federal Fisheries Act and Clean Air Act. However, the Federal Government has not as yet developed specific point source emission requirements for oil sands facilities. In light of the location and nature of oil sands developments, emphasis to date has been placed on meeting provincial environmental requirements.

In the determination of the requirements for flue gas treatment and in the development of wastewater treatment schemes for the 15 selected options, relevant federal and provincial emissions regulations and guidelines were reviewed. Both federal and provincial guidelines with respect to emissions from coal-fired utility boilers were used in establishing emission limits for flue gas from CO and residue fired boilers. In regard to SO_2 emissions from the oil sands complexes, the province's future goal of 3.2 tonnes $SO_2/1000\ m^3$ bitumen feed to upgrading is used to determine desulphurization requirements.

4.2 RECYCLING/REUSE OF RESIDUALS AND BY-PRODUCTS

Coke or pitch residues from primary upgrading and other byproducts from bitumen upgrading including CO gas (fluid coking) and process gas are utilized in this study to illustrate alternate methods for byproduct reuse. As discussed in Part 2, verification of the application of residue utilization in utility boilers and fluidized bed boilers is required before commercial implementation. Similarly, gasification of coke or pitch to a medium joule fuel gas for use in utility boilers or in the manufacture of hydrogen requires demonstration. The composition of residues and other byproducts was derived from in-house data.

The following summarizes the methods assumed in this study for byproduct reuse and represents a range of processes which may be included in a future energy efficient oil sands complex:

1. In all options, process gas is stripped of acid gases in the amine plant and is utilized as a fuel in the upgrading fired heaters, utility boilers and superheaters.

2. CO gas from the fluid coking options (Options 1, 2, 8 and 11) is combusted with process gas in the CO boilers. Table 4-1 provides the composition of the CO gas assumed for combustion calculations.

3. Coke produced from the fluid coking options is pulverized and combusted with process gas in the conventional-type coke boilers in Options 1 and 11. In Option 8, the coke is combusted in fluidized bed boilers. Coke is gasified in Option 2 to produce a medium joule fuel gas. The fuel gas, after removal of acid gases, is utilized in utility boilers for steam generation. Table 4-2 provides the assumed coke composition.

4. Low joule fuel gas from Flexicoking (Options 3, 8 and 14) is utilized in utility boilers after fines removal and acid gas stripping. Table 4-3 provides the estimated composition of the flexigas.

5. Pitch from the H-Oil primary upgrading process is utilized as a fuel in conventional-type utility boilers (Option 4) or is gasified and subsequently utilized in the manufacture of hydrogen (Options 5 and 12). Table 4-4 provides the assumed pitch composition.

6. Residues from the CANMET primary upgrading process (Options 6 and 13) are utilized as a fuel in fluidized bed boilers. The composition of the pitch has been estimated and is provided in Table 4-5.

7. Pitch from the Eureka primary upgrading process (Option 7) is gasified to produce a medium joule fuel gas. The fuel gas is stripped of acid gases by amine contact and is utilized as a fuel in utility boilers. Table 4-6 shows the estimated pitch composition.

8. In the direct coking options (Options 10 and 15), the pyrolosis products of direct coking are combusted within the lift pipe to provide process heat. Any residual carbon is discharged with the spent sand.

4.3 COLLECTION AND TRANSPORT

The collection and distribution network for liquid and solid wastes from mining, extraction, upgrading, utilities and offsites has been established conceptually for this study. This has enabled the routing of various wastewater streams from individual process units to a series of sewer lines and drainage ditches which carry wastewater of similar quality to required treatment systems or to discharge points. Similarly, solid wastes are identified at their respective generation

TABLE 4-1

CO Gas Composition
Options 1, 2, 8 and 11

Component	Composition mole %
CO_2	11.10
CO	3.17
H_2	0.89
CH_4	0.82
COS	0.06
SO_2	0.23
H_2S	0.09
NH_3	0.13
N_2	59.93
H_2O	23.58

TABLE 4-2

Fluid Coke Composition
Options 1, 2, 8 and 11

Component	Composition (wt%)	
	Options 1, 2 and 11	Option 8
C	77.4	81.2
H	1.5	1.6
N	0.6	0.6
O	4.5	4.7
S	7.9	8.3
Ash	8.2	3.7

TABLE 4-3

Flexigas Composition
Options 3, 8 and 14

Component	Composition mole %
CO_2	7.73
CO	16.03
H_2	7.42
CH_4	1.19
COS	0.01
H_2S	0.07
NH_3	0.05
N_2	57.08
H_2O	10.42

TABLE 4-4

H-Oil Pitch Composition
Options 4, 5 and 12

Component	Composition wt.%
C	72.0
H	6.5
N	1.5
S	3.5
O	1.5
Ash	14.5
V	590 ppm
Ni	500 ppm

TABLE 4-5

CANMET Pitch Composition
Options 6 and 13

Component	Composition wt.%
C	70.5
H	5.9
N	2.1
S	3.2
O	2.0
Ash	16.2
V	570 ppm
Ni	490 ppm

TABLE 4-6

Eureka Pitch Composition
Options 7

Component	Composition wt.%
C	80.0
H	5.0
N	1.0
S	7.5
O	1.5
Ash	5.0

points and are transported to the mined-out area for disposal, to storage areas or off-site for clean-up and regeneration. This conceptual network for collection and distribution of wastes forms the basis of the pollutant flow diagrams presented in Part 5.

Emissions to the atmosphere have been identified at their point of origin. While there are merits as well as concerns with the utilization of common stacks for venting gaseous emissions to the atmosphere, detailed analyses are required. For the purposes of this study, all emissions to the atmosphere are identified as individual emission sources.

431 WASTEWATER COLLECTION AND DISTRIBUTION NETWORK

Liquid waste streams from individual process units are directed to specific sewer lines or drainage ditches which transport wastewaters to required treatment systems or to discharge points. The collection network is conceptual, established to transport wastewater of similar quality to common treatment or disposal points. In some cases, the conceptual sewer line may be a series of separate sewers or ditches. The following identifies the conceptual wastewater collection network.

.1 Tailings Line

The tailings line is made up of a series of slurry pipelines capable of transporting wet tailings from hot water extraction to the tailings pond. Wet tailings from froth treatment are transported to the tailings pond by a separate line. Mine water, which is also identified as an input to the conceptual tailings line in the tailings pond options, would simply be pumped from the mine to the in-pit tailings pond.

.2 Process Waste Sewer

All process wastewaters containing oil and grease or other constituents requiring treatment are discharged to the process waste sewer. Included in this conceptual line is runoff from the in-plant area. Runoff, which is collected from the plant area in a series of ditches and storm sewers would be combined with the process wastewaters immediately prior to the treatment facilities to enable equalization of runoff flows in the storm pond during the spring runoff period or under storm conditions. In the options without a tailings pond, effluent from the sewage treatment plant is discharged to the process waste sewer.

.3 Recycle Sewer

Wastewater which may be recycled for various plant uses is collected in the recycle sewer and is transported to the recycle pond.

These wastewaters include boiler blowdown and other clean condensate. In options without a tailings pond, effluent from the treatment of process wastewaters is returned to the recycle pond.

.4 Effluent Sewer

Wastewaters which are high in total dissolved solids but otherwise relatively uncontaminated are discharged to the effluent sewer. These wastewaters include cooling tower blowdown and neutralized regenerant wastewater from the utilities water treatment plant. In the options with a tailings pond, these wastewaters along with prescrubber blowdown from flue gas desulphurization and effluent from the sewage treatment plant are discharged to the effluent pond and subsequently are pumped to the tailings pond. In the remaining options, the cooling tower blowdown and neutralized regenerant wastewater are discharged, subject to compliance with discharge regulations relative to total dissolved solids and other parameters.

.5 Sludge Sewer

Alum sludge from the potable water treatment plant and digested sewage sludge are conveyed to the sludge pond via the sludge sewer.

.6 Sour Water Sewer

In Options 10 and 15, sour water separated from the intermediate products in the direct coking process contains high concentrations of phenols and fatty acids, as reported by the licensor. Steam extractable phenols and ammonia are steam stripped from the sour water within the direct coking process prior to discharge to the sour water sewer. In these options, stripped sour water from the sour water stripper in the upgrading area is also discharged to the sour water sewer. This sewer transports the wastewater to a separate high rate biological treatment system.

.7 Drainage Ditch

The conceptual network of drainage ditches carries runoff from areas of the complex which are not subject to contamination, runoff from overburden storage areas and water from mine dewatering programs to natural drainage channels in the area of the mining oil sands complex.

.8 Mine Drainage

For the options without a tailings pond, mine water is pumped to the mine drainage line which carries the wastewater to the sediment pond.

.9 Filtrate Line

Filtrate from vacuum filtration of whole tailings (Options 2, 5, and 12) is returned to the hot water extraction process.

.10 Other

Other liquid wastes are transported off-site for utilization or treatment and disposal. Byproduct from the ammonia scrubbing systems is transported off-site for utilization as a feedstock in the manufacture of ammonia fertilizer, or possibly for direct fertilizer application. Tank bottoms are transported off-site for treatment and disposal at a hazardous waste facility, or possibly disposed of by land farming.

432 SOLID WASTE COLLECTION AND DISTRIBUTION NETWORK

Solid wastes from extraction, upgrading, utilities and offsites which are landfilled in the mined-out area are transported by conveyors or by trucks. The establishment of the mode of solid waste transport requires detailed economic and engineering analyses, however, in general it is expected that solids which are generated in large quantities and continuously are transported by conveyors. This would include rejects from extraction, dry tailings from the tailings filtration and solvent extraction options, and spent sand from the direct coking options.

Solid wastes which are generated in smaller quantities, or which may be produced periodically, such as incinerator ash, would invariably be trucked to disposal. Other solid wastes, including fly ash, bottom ash, spent bed material from fluidized bed boilers, slag and char from gasification, and char and fines from flexicoking which are generated at rates up to 2200 tonnes per day, are also expected to be trucked to disposal. Trucking of these wastes minimizes double handling of the material at the plant site and at the disposal site.

Other solid waste streams from the complex include overburden materials from the mining operation which are disposed of directly in the mine, sulphur which is stored in the sulphur block prior to transport off-site as a saleable byproduct, and spent catalysts from the H-Oil reactor. It is assumed that spent catalysts are trucked off-site for clean-up and regeneration.

4.4 FLUE GAS TREATMENT

441 EMISSIONS CRITERIA

The required degree of flue gas treatment for emission sources from the oil sands complexes in this study has been established from a review of the Alberta Clean Air Act and regulations thereunder, the Sulphur Recovery Guidelines of Alberta Energy Resources Conservation Board, federal and provincial guidelines for fossil fuel-fired steam-electric power plants, and Alberta Environment's long-term objective for controlling sulphur emissions from oil sands plants. Although the federal and provincial guidelines for steam-electric power plants may not be directly applicable to oil sands plants, it is expected that the emission guidelines would apply to those oil sands fuels, combustion devices and flue gas streams which are amenable to the same pollutant control technologies and removal efficiencies as conventional power plants.

The emissions from the utility boilers and sulphur recovery plants in the oil sands complexes have been computed on the basis of the following criteria:

1. 99.9% sulphur recovery efficiency in the sulphur plant. This is achievable with currently available technology.

2. Overall plant emission limit of 3.2 tonnes $SO_2/1000\ m^3$ bitumen feed to upgrading which represents the long-term objective of Alberta Environment for sulphur emissions from future oil sands plants. The limit was used to compute the required sulphur removal efficiencies for CO, coke and pitch boilers.

3. Maximum particulate emissions of 0.2 grams per kilogram of wet flue gas adjusted to 50% excess combustion air.

4. Maximum NO_x (as NO_2) emissions of 86 nanograms per joule for conventional gaseous fuels and 258 nanograms per joule for solid fuels.

In addition to the above, ambient air quality limits for SO_2, H_2S, NO_2, CO, oxidants as equivalent O_3 and suspended particulates also apply to oil sands plants.

442 FLUE GAS TREATMENT REQUIREMENTS

The flue gas treatment requirements to achieve the established emissions criteria are summarized in Table 4-7. For all options, it is assumed that 99.9% sulphur recovery is achieved in the sulphur recovery plant and H_2S from sour water stripping, storage tanks and other sources is routed to the sulphur plant for recovery.

It is assumed that sulphur removal by desulphurization of flue gases from all CO boilers is 90%, and a similar removal efficiency is assumed by limestone addition in the coke or pitch fired fluidized bed boilers. The required removal efficiencies for flue gases from conven-

TABLE 4-7

Flue Gas Treatment Requirements

Option	Boiler	Particulate Removal	SO_2 Removal (Efficiency)
1	CO Boilers	ESP	FGD (90%)
	Coke Boilers	ESP	FGD (87.5%)
2	CO Boilers	ESP	FGD (90%)
4	Pitch Boilers	ESP	FGD (40.6%)
6	Pitch Boilers	ESP	FBC (90%)
8	CO Boilers	ESP	FGD (90%)
	Coke Boilers	ESP	FBC (90%)
11	Co Boilers	ESP	FGD (90%)
	Coke Boilers	ESP	FGD (87.7%)
13	Pitch Boilers	ESP	FBC (90%)

ESP Electrostatic Precipitators
FGD Flue Gas Desulphurization
FBC Fluidized Bed Combustion (Atmospheric)

tional-type coke or pitch boilers are calculated from the overall plant SO_2 emission limit. Further, it has been assumed that NO_x emissions are controlled by boiler design factors and operational measures.

443 FLUE GAS DESULPHURIZATION

.1 Optional Processes

There are a great number of processes for the scrubbing of the offgases from an oil sands complex for the removal of SO_2. Operating experiences with these processes are mainly in the United States where the American utility industry, in response to the requirements of the 1970 Clean Air Act amendment, has had a relatively long history of removing SO_2 from offgases. This industry has acquired considerable learning experience in terms of developing scrubbing technology and equipment, as well as in waste byproduct disposal.

The early systems in the American utility industry were dominated by wet lime or limestone scrubbing systems, principally because of cost considerations and the availability of inexpensive reagents. Although this dominance continues today and will probably continue in the future, a number of other technologies have been and continue to be developed. The processes that have had some operational experience in the American utility industry are summarized in Table 4-8. Included are processes generating a saleable product and those for which the byproducts are throwaway.

The 1979 amendments to the Clean Air Act in the United States, which required a minimum of 70% reduction of SO_2 emissions from utility plant offgases, have put additional pressure on the development of sulphur reduction processes, including burner modifications. Additional experience in operating FGD systems is available from other sources including the oil fired utility industry in Japan, the pulp and paper industry, and at Cominco in Trail, B.C.

Several evaluations have been performed to assess the applicability of scrubbing systems to oil sands complexes (Stone and Webster 1978, Dynawest Projects Limited 1981, Monenco 1981). The processes that have been evaluated include lime scrubbing, limestone scrubbing, Wellman-Lord, dual alkali, magnesium oxide scrubbing, Chiyoda 121, Shell copper oxide system, lime spray drying and ammonia scrubbing.

.2 System Design Criteria

Recognizing the nature of an oil sands extraction and upgrading complex, a number of criteria would have to be met for systems to warrant serious consideration. These criteria include the following (Monenco 1981):

TABLE 4-8

Flue Gas Desulphurization Processes
in U.S. Utility Industry

Processes Generating Saleable Byproducts	Processes Generating Throwaway Byproducts
Aqueous Carbonate/Spray Drying	Dual Alkali
Citrate	Lime
Lime	Limestone
Limestone	Limestone/Alkaline Fly Ash
Lime/Limestone	Lime/Alkaline Fly Ash
Magnesium Oxide	Lime/Limestone
Wellman Lord	Lime/Sodium Carbonate
	Lime/Spray Drying
	Sodium Carbonate
	Sodium Carbonate/Spray Drying

- high reliability - the scrubbing system's reliability must be as good as that of the operating unit producing the offgases;

- scrubbing efficiency - SO_2 removal capability must be a minimum of 90%;

- simplicity - to avoid adding operational problems to an already complex facility, the scrubbing system must be simple (single stage scrubbing) with minimal processing beyond scrubbing;

- high turndown - the scrubbing system must have a turndown ratio at least as high as the units generating the offgases, which would be in the order of 2.5:1;

- redundancy - a high level of redundancy is required in all critical equipment items;

- performance guarantee - only those systems for which a vendor performance guarantee could be obtained are to be considered;

- site conditions - the design must accommodate the severe weather conditions and remote location of the oil sands region of northern Alberta.

.3 Candidate System

A detailed review of all the candidate systems meeting the design criteria outlined above resulted in the choice of ammonia scrubbing as the system most applicable for an oil sands complex. In addition to the process evaluation, this decision also had the benefit of visits to several operating FGD systems, including ammonia scrubbing systems at Cominco in Trail, B.C.; Finch/Pruyn Pulp and Paper in Adirondack, N.Y.; and Shattuck Chemicals in Denver, Colo.

The longest experience in ammonia scrubbing comes from Cominco, where they have been operating such a system to reduce sulphur emissions from their zinc ore roasters for over 35 years. The introduction of ammonia scrubbing in the 1940's allowed Cominco to integrate their scrubbing system into an overall complex producing an additional product in the form of fertilizer. The system has operated extremely well on a wide range of SO_2 concentrations up to 8% by volume (80 000 ppmv SO_2). Cominco has recently designed and constructed a new ammonia scrubbing system to treat about 2400 m^3/min to replace the original system, which after 35 years of operation has suffered some structural problems.

.4 Process Description

Figure 4-1 shows a simplified process flow diagram of an ammonia scrubbing system. Flue gases from the process unit (CO boiler or utility boiler) are passed through an electrostatic precipitator for the

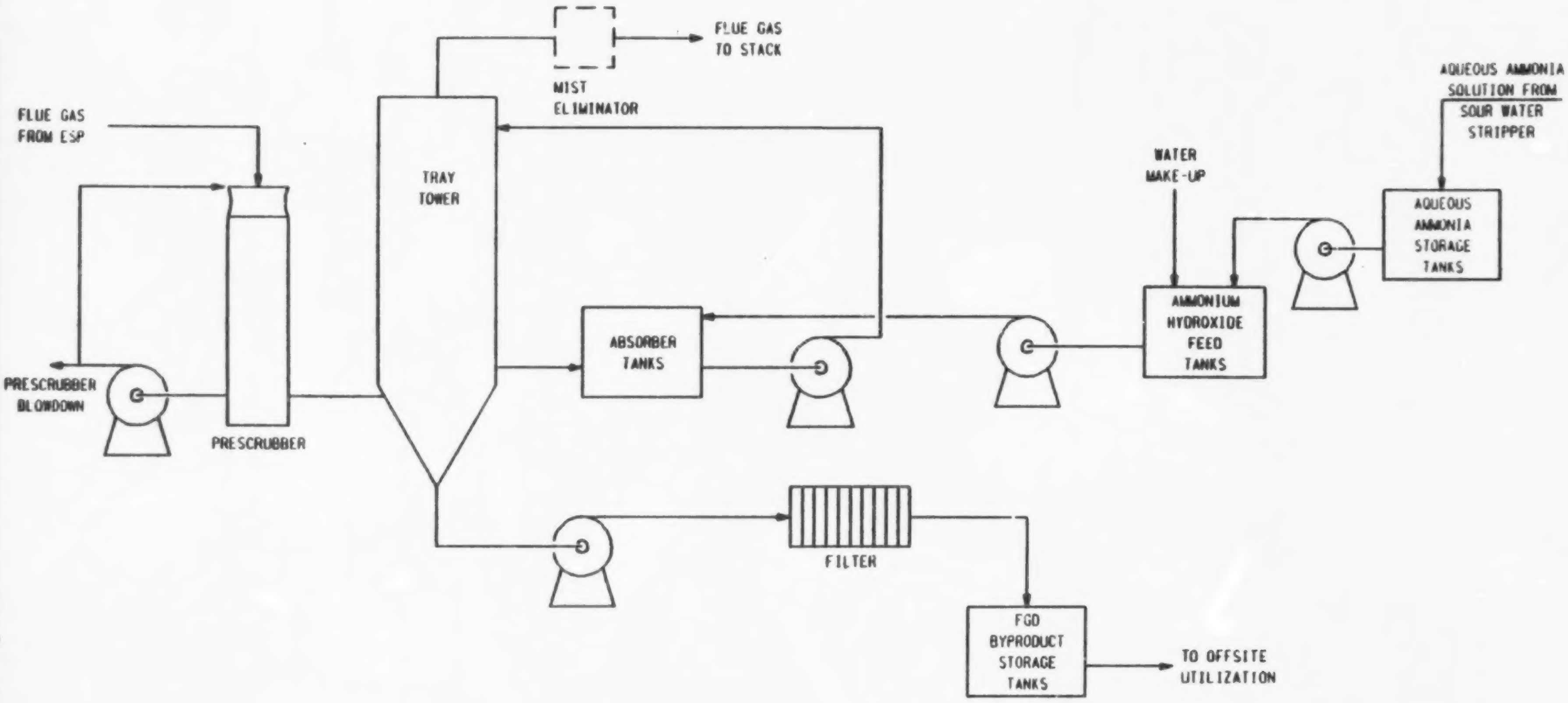
FLUE GAS
FROM ESP
PRESCRUBBER
BLOWDOWN
PRESCRUBBER
TRAY
TOWER
MIST
ELIMINATOR
FLUE GAS
TO STACK
ABSORBER
TANKS
FILTER
FGD
BYPRODUCT
STORAGE
TANKS
TO OFFSITE
UTILIZATION
WATER
MAKE-UP
AMMONIUM
HYDROXIDE
FEED
TANKS
AQUEOUS
AMMONIA
STORAGE
TANKS
AQUEOUS AMMONIA
SOLUTION FROM
SOUR WATER
STRIPPER

FIGURE 4-1

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

AMMONIA SCRUBBING FLUE
GAS DESULPHURIZATION

MONENCO CONSULTANTS LIMITED

removal of particulates, from which gases flow into a prescrubber for saturation and cooling. Additional particulate removal may also occur within the prescrubber. A high flow rate of scrubbing solution is maintained through the prescrubber section. The prescrubber is purged to maintain the overall water balance. Cooling is required since efficient absorption of SO_2 by aqueous solutions of ammonia requires gas temperatures well below 20°C, which is below the saturation point of the off-gases. As a result, condensation of water from the gases to be scrubbed occurs.

Gases from the prescrubber/cooler unit pass through mist eliminators for the removal of entrained liquid and then enter the absorber tower. The number of stages in the absorber is a function of the requirements of the scrubbing system, but would vary between two and four. Each tray of the counter-current absorber is fed from its own absorber recirculation tank in order to maintain and control conditions on each tray. The gases exiting the last tray pass through at least one stage of mist elimination. Depending on the requirements for opacity in the exhaust gases, a second stage of mist elimination may be required in the form of a fabric filter (Brinks eliminator) or wet electrostatic precipitator.

The ammonia reagent for the scrubbing system is obtained from the sour water stripper system. In order to provide the purity required in the ammonia scrubbing system, at least one and possibly two stages of stripping are required beyond the primary sour water stripping unit. The aqueous ammonia solution is fed to a storage tank from where it is pumped into a feed tank where it is diluted to the concentration required by the scrubbing system. The absorber circulating tanks which feed each tray receive make-up from the ammonia feed tank. The absorber bottoms, consisting mainly of ammonia bisulphite, are filtered and pumped to a product storage tank. The concentration of this material is approximately 250 to 400 g/L as ammonium bisulphite. Disposal options are as a direct application fertilizer or as a feedstock to the fertilizer industry.

444 FLUIDIZED BED BOILERS

Fluidization and the combustion of materials in a fluidized bed are not new technologies. Fluidization was first used on a large scale for gasifying coal in 1922 and became commerical in Germany in 1926 in the Winkler gas generator (Johnson et al. 1978). Urged by the wartime need to develop new methods of producing high octane aviation fuels, the petrochemical industry in the United States developed the fluidized bed catalytic cracking process which realized significant increases in production rates over fixed fed technology. Experiments in the generation of steam by combustion of materials in a fluidized bed began just after the Second World War with the first patent in which raising steam was a purpose of fluidized bed combustion being granted in 1950 (Ehrlich 1975).

Fluidized bed incinerators were also developed to handle wastes from wood, paper and pharmaceutical industries just after the Second World War. These fluid bed combustion systems provided a technical basis for the development of the fluidized bed for the purposes of large scale steam generation. A considerable amount of effort has been expended in several countries since the Second World War in evaluating the potential of fluidized bed combustion for power generating units. In the United States, this effort has been led by the consulting firm of Pope, Evans and Robbins, Battelle Memorial Institute's Columbus Laboratories, Babcock and Wilcox and Combustion Engineering (Johnson et al. 1978). In England, fluidized bed combustion development was started by the Central Electricity Generating Board in about 1959 and shortly thereafter was transferred to the National Coal Board's Coal Research Establishment which has conducted a wide range of research on the subject.

Fluidized bed boilers fall into two general categories: atmospheric and pressurized. The latter takes place typically under pressures between three and ten atmospheres. In either case, the fluidization part of the process is relatively straightforward. In an oil sands plant, the fluidized bed would consist of pulverized coke or pitch and limestone with the size distribution of the bed particles designed to ensure good fluidizing characteristics. The bed is supported on a grid or perforated plate through which the fluidizing medium, preheated air, passes. In the fluidized state, the bed expands to a height two to four times the unfluidized level. The particulates entrained from the bed, consisting of up to 15% unburnt coke, are removed by one or two stages of cyclone separators located external to the bed or at the top of the boiler. Material collected in the cyclones is returned to the bed, while that escaping the cyclones is collected by particulate removal equipment such as a baghouse or an electrostatic precipitator. The non-combustible inorganic fraction that escapes entrainment and remains in the bed is drained from the bed for disposal as spent bed material.

The injection of limestone into the bed results in the preferential reaction of the sulphur contained in the coke with limestone to form a sulphate which remains in the inorganic fraction of the bed. Thermodynamics are highly favourable for this reaction to occur as opposed to the formation of sulphur dioxide. In addition to sulphur removal within the fluidized bed boiler, additional advantages of fluid combustion include:

1. The combustion temperature considerably below that of a conventional boiler. This temperature range is below the point of fixation of nitrogen to form NO_x and hence NO_x emissions are expected to be significantly reduced over conventional boilers. The range of combustion temperatures is also below the fusion temperature of the coke particles which prevents slagging and the formation of clinkers. The ash produced is more easily handled, while the need for soot blowing is reduced.

2. The fluidized bed operation approaches isothermal conditions. This good temperature control feature reduces the potential for hot spots to develop and hence reduces the need to add temperature margins and heat transfer material selection. In addition, carbon burn-up may be as high as 99.9%.

3. A wide range of material can be combusted in the bed.

4. Heat transfer is enhanced within the bed. Heat transfer coefficients governing the transfer of heat from the bed proper to pipework submerged in the bed are significantly higher than those for the transfer of heat in a conventional boiler. This gives rise to the potential reduction in required heat transfer areas and hence a reduction in boiler size.

5. Trace metal discharges, either in vapour form or adsorbed onto fine particles, are less in a fluidized bed because of the reduced temperature.

A further discussion of the advantages and disadvantages of fluidized bed combustion for thermal power generation can be found in Behie (1981).

445 PARTICULATE REMOVAL

The options for removal of particulates from process offgases in an oil sands plant include electrostatic precipitation, baghouse separation and wet Venturi scrubbing. Based on operating experience in an existing oil sands plant and the experiences in the Canadian utility industry in removing particulates from offgases, electrostatic precipitation was chosen as the basis for particulate removal for this study. In the operation of a precipitator, the dust laden gases, under controlled conditions, pass through a corona discharge which imparts a charge to the particulates which are then removed under the influence of the high voltage field to a collector plate. Occasional rapping of the plate discharges the collected particulates into the hoppers beneath the precipitators, from where the solids are pneumatically fed to a storage silo. From the storage silo, the particles are wetted and loaded onto trucks for transport to the mine for disposal.

4.5 WASTEWATER TREATMENT

The wastewater characterization data base, presented in Part 3, is representative of the available information from published sources. While the data base is extensive, there are significant gaps in the data which affect the decisions regarding wastewater treatment systems as well as creating concerns with respect to the ability to recycle or discharge wastewaters.

These gaps in the data are mainly in the area of trace element and trace organic loads in various liquid waste streams and identification of the constituent parts of total organics. In addition, biodegradability data is limited.

On the basis of the reported characterization data, wastewater treatment schemes have been established for each option. These schemes are shown on the pollutant flow diagrams presented in Part 3. The nature of the unit processes within the selected options and wastewater characteristics has necessitated the establishment of four base wastewater management schemes, as follows:

1. Wastewater Treatment Scheme - Tailings Pond Options,
2. Wastewater Treatment Scheme - Tailings Filtration Options,
3. Wastewater Treatment Scheme - Solvent Extraction Options, and
4. Wastewater Treatment Scheme - Direct Coking Options.

Within each of these schemes, treatment components have been selected and sized to permit order-of-magnitude cost estimation of wastewater treatment. In all options, the wastewater treatment components are conventional technologies with proven effectiveness in treating wastewaters from the oil and gas industry. There are other alternatives but in consideration of the magnitude of wastewater flows requiring treatment (up to 26 300 m^3/sd); the climatic constraints of the Athabasca oil sands region; the necessity for proven and reliable performance; and the lack of complete characterization and treatability data, conventional wastewater treatment components have been selected. Further information on trace elements and organics may necessitate modifications to the wastewater management schemes; for example, the use of activated carbon may be required to remove trace organics.

Factors which are common to all wastewater treatment schemes and assumptions used in selecting and sizing the treatment components are provided as follows:

1. Stream day wastewater flows are used to size the wastewater treatment components and are representative of maximum daily wastewater flows under normal conditions. However, some liquid waste streams occur only intermittently or during certain periods of the year. Flow equalization may be required and would have the effect of decreasing the size of some treatment components.

2. In all options, a storm pond is provided to store in-plant runoff when flows are in excess of downstream treatment capabilities. This would occur during the spring runoff period and under storm conditions. The storm ponds are sized to provide storage for expected spring runoff plus runoff from the plant site as a result of the 1 in 10 year 24 hour storm. Downstream treatment component capabilities are adjusted to enable treatment of increased stream flows as a result of draining the storm pond over a 30-day period. Should runoff flows exceed the combined storage capacity of the storm pond and capabilities of the treatment units, which may occur during a runoff event from the 1 in 25 year storm, discharge from the storm pond may be required. It is expected that drainage control and runoff holding facilities would be incorporated in the design of an oil sands complex, thus minimizing the possibility of discharge from the storm pond.

3. All ponds which make up part of the wastewater treatment systems are earthen structures with interior dykes sloped at 2 to 1 with a freeboard of 1 m. All ponds are lined to prevent seepage and provide containment of contaminants. For costing purposes, hypalon liners placed on a prepared base are assumed for all ponds.

4. In all options, sludge ponds are provided within the waste treatment systems. Thickening of sludge takes place within the ponds and is enhanced by natural freeze-thaw mechanisms during the winter months. It is assumed that ultimately, the solids concentration within the sludge ponds will reach 25% by weight. Supernatant is removed during the frost-free months and is directed to treatment. With the exception of Option 10, the sludge ponds are sized to store thickened sludge quantities generated over 25 years. In Option 10, the sludge generation from the treatment of sour water from direct coking is considerable. Therefore, in Option 10 it is assumed that removal of sludge from the sludge ponds is required every 5 years in order to reduce the size of the ponds.

   At the end of the operating life of the complex, the sludge ponds would be reclaimed as part of the overall plant decommissioning program. It is assumed that, subject to the integrity of the pond liners, a cover material would be applied, the surface would be sloped and sealed and a long-term monitoring system established.

5. Maximum recycle of wastewaters is assumed in all options. This takes the form of direct recycle from the recycle ponds, reclamation of water from the tailings ponds and recycle of treated wastewater. Water quality requirements within extraction, upgrading, utilities and offsites may place constraints on the

ability to recycle available quantities of waters. Further treatment may be required to meet the water quality constraints of certain water uses. A comprehensive chemical analysis of water available for recycle, undertaken with the benefit of complete wastewater characterization information, is required to ascertain recycling possibilities over the long-term. Should discharge of a portion of the treated wastewater be required, an additional holding pond would be included in the wastewater treatment system. As well, further treatment may be required to meet discharge limits imposed by regulatory agencies.

In this section, the wastewater treatment schemes are described and the individual treatment components are identified.

451 WASTEWATER TREATMENT SCHEME - TAILINGS POND OPTIONS (Options 1, 3, 4, 6, 7, 11 and 13)

The wastewater treatment scheme for the tailings pond options is shown in Figure 3-2. Wastewater treatment systems for these options are less extensive than systems required for other options due to the presence of the large tailings pond. With the exception of wastewater which is recycled to the oil sands complex directly from the recycle pond and discharges of uncontaminated runoff, all wastewaters are ultimately discharged to the tailings pond. After considerable retention within the pond, water is recycled to hot water extraction.

Tailings from hot water extraction and froth treatment are pumped via slurry pipelines directly to the tailings pond. Similarly mine water is pumped directly to the pond. Process wastewater (including in-plant runoff) flows initially to the API separator where free oil rises to the surface within the multi-channel separator and is skimmed off into recovered oil tanks. The recovered oil is directed back to the plant. Suspended solids settle out within the separator and are removed and pumped to the sludge pond. A spare channel is provided in the API separator to enable clean-up and maintenance and to increase the capacity of the unit during runoff events. Effluent from the API separator is directed to the effluent pond.

Other input streams to the effluent pond include supernatant from the sludge pond and wastewater carried by the effluent sewer (cooling tower blowdown, regenerant wastewater, treated sewage effluent, etc.). From this point the wastewater is pumped to the tailings pond.

Sludge from unit processes within the oil sands complex and sludge from the API separator are discharged to the sludge pond for thickening and disposal. Wastewater, which may be recycled directly for various in-plant uses, is collected in the recycle pond.

Discharges from the system are limited to uncontaminated runoff from the plant area, runoff from overburden storage and water from mine dewatering programs.

Tables 4-9 to 4-15 provide a summary of the components which make up the wastewater treatment system for the options with a tailings pond.

452 WASTEWATER TREATMENT SCHEME - TAILINGS FILTRATION OPTIONS (Options 2, 5 and 12)

The wastewater treatment scheme in these options differs considerably from the tailings pond options. Since the tailings pond is not available to provide any additional wastewater treatment, an extensive wastewater treatment system is required. The wastewater treatment scheme is shown in Figure 3-3. The following summarizes the major components of the wastewater treatment scheme:

1. Process wastewater which requires treatment is directed to the API separator for free oil and suspended solids removal. Oil is collected in recovered oil tanks and is subsequently returned to the plant. Suspended solids are pumped to the sludge pond. Similar to all other options, a spare channel is provided in the API separator.

2. Effluent from the API separator flows to the dissolved air flotation units for further oil removal. A flocculant and polymers are added upstream of the units, and flocculation occurs prior to the introduction of air. The scum from the flotation units is skimmed from the surface and directed to the sludge pond.

3. Further reduction of BOD load in the wastewater is accomplished in the activated sludge system. Since the oxygen demand of the wastewater in the process waste sewer is not accurately defined, it has been assumed that the BOD of the wastewater as it enters the activated sludge system is 250 mg/L. Following biological oxidation, solids are settled in the clarifier. Waste activated sludge from the system is pumped to the sludge pond.

4. Further suspended solids removal is achieved in the dual media filters. Although filtration of only a portion of the wastewater may be required, it has been assumed that the entire stream is filtered. Backwash water from the filters is returned to the inlet of the dissolved air flotation unit.

TABLE 4-9

Wastewater Treatment Systems
Option 1[1]

Component	Size[2]	Capacity
API Separator	3 channels: each 50 m x 4.7 m x 2 m	15 900 m^3/sd
Effluent Pond	94 m x 94 m x 5 m	26 690 m^3
Storm Pond	264 m x 264 m x 5 m	252 950 m^3
Sludge Pond	2 ponds: each 162 m x 162 m x 6 m	219 960 m^3
Recycle Pond	36 m x 36 m x 5 m	2 250 m^3
Reclaim Pond	294 m x 294 m x 6 m	393 140 m^3
Sewage Treatment Plant	RBC Unit	1 140 m^3/sd

Notes: [1] Option 1 - Hot Water Extraction/Fluid Coking/CO and Coke Boilers
[2] Pond dimensions include 1 m freeboard

TABLE 4-10

Wastewater Treatment Systems
Option 3(1)

Component	Size(2)	Capacity
API Separator	3 channels: each 50 m x 4.7 m x 2 m	16 040 m^3/sd
Effluent Pond	93 m x 93 m x 5 m	26 290 m^3
Storm Pond	264 m x 264 m x 5 m	252 950 m^3
Sludge Pond	2 ponds: each 152 m x 152 m x 6 m	190 120 m^3
Recycle Pond	36 m x 36 m x 5 m	2 250 m^3
Reclaim Pond	294 m x 294 m x 6 m	393 140 m^3
Sewage Treatment Plant	RBC Unit	1 140 m^3/sd

Notes: [1] Option 3 - Hot Water Extraction/Flexicoking/Flexigas Boilers
[2] Pond dimensions include 1 m freeboard

TABLE 4-11

Wastewater Treatment Systems
Option 4(1)

Component	Size(2)	Capacity
API Separator	3 channels: each 50 m x 4.2 m x 2 m	14 820 m^3/sd
Effluent Pond	89 m x 89 m x 5 m	23 640 m^3
Storm Pond	264 m x 264 m x 6 m	252 950 m^3
Sludge Pond	2 ponds: each 156 m x 156 m x 6 m	203 010 m^3
Recycle Pond	36 m x 36 m x 5 m	2 250 m^3
Reclaim Pond	272 m x 272 m x 6 m	332 460 m^3
Sewage Treatment Plant	RBC Unit	1 140 m^3/sd

Notes: [1] Option 4 - Hot Water Extraction/H-Oil/Pitch Boilers
[2] Pond dimensions include 1 m freeboard

TABLE 4-12

Wastewater Treatment Systems
Option 6(1)

Component	Size(2)	Capacity
API Separator	3 channels: each 50 m x 4.1 m x 2 m	14 370 m^3/sd
Effluent Pond	87 m x 87 m x 5 m	22 490 m^3
Storm Pond	264 m x 264 m x 5 m	252 950 m^3
Sludge Pond	2 ponds: each 152 m x 152 m x 6 m	189 740 m^3
Recycle Pond	36 m x 36 m x 5 m	2 250 m^3
Reclaim Pond	265 m x 265 m x 6 m	313 990 m^3
Sewage Treatment Plant	RBC Unit	1 140 m^3/sd

Notes: [1] Option 6 - Hot Water Extraction/CANMET/Pitch Boilers (FBC)
[2] Pond dimensions include 1 m freeboard

TABLE 4-13

Wastewater Treatment Systems
Option 7[1]

Component	Size[2]	Capacity
API Separator	3 channels: each 50 m x 5.8 m 2 m	20 440 m^3/sd
Effluent Pond	100 m x 100 m x 5 m	30 820 m^3
Storm Pond	264 m x 264 m x 5 m	252 950 m^3
Sludge Pond	2 ponds: each 152 m x 152 m x 6 m	190 710 m^3
Recycle Pond	36 m x 36 m x 5 m	2 250 m^3
Reclaim Pond	290 m x 290 m x 6 m	381 080 m^3
Sewage Treatment Plant	RBC Unit	1 140 m^3/sd

Notes: [1] Option 7 - Hot Water Extraction/Eureka/Gasification of Pitch
[2] Pond dimensions include 1 m freeboard

TABLE 4-14

Wastewater Treatment Systems
Option 11(1)

Component	Size(2)	Capacity
API Separator	3 channels: each 37.5 m x 3.4 m x 1.5 m	4 420 m^3/sd
Effluent Pond	53 m x 53 m x 5 m	6 790 m^3
Storm Pond	190 m x 190 m x 5 m	126 470 m^3
Sludge Pond	2 ponds: each 113 m x 113 x m x 6	97 120 m^3
Recycle Pond	21 m x 21 m x 3 m	330 m^3
Reclaim Pond	123 m x 123 m x 6 m	58 970 m^3
Sewage Treatment Plant	RBC Unit	570 m^3/sd

Notes: [1] Option 11 - Hot Water Extraction/Fluid Coking/CO and Coke Boilers
[2] Pond dimensions include 1 m freeboard

TABLE 4-15

Wastewater Treatment Systems
Option 13[1]

Component	Size[2]	Capacity
API Separator	2 channels: each 37.5 m x 3.2 m x 1.5 m	4 190 m^3/sd
Effluent Pond	51 m x 51 m x 5 m	5 990 m^3
Storm Pond	190 m x 190 m x 5 m	126 470 m^3
Sludge Pond	2 ponds: each 111 m x 111 m x 6 m	93 470 m^3
Recycle Pond	21 m x 21 m x 3 m	330 m^3
Reclaim Pond	111 m x 111 m x 6 m	47 100 m^3
Sewage Treatment Plant	RBC Unit	570 m^3/sd

Notes: [1] Option 13 - Hot Water Extraction/CANMET/Pitch Boilers (FBC)
[2] Pond dimensions include 1 m freeboard

5. Effluent from the dual media filters is pumped to the recycle pond and, along with wastewater carried to the pond by the recycle sewer, is routed back to the plant for various uses.

6. Sludge from unit processes within the oil sands complex is transported via the sludge sewer to the sludge pond. Other inputs to the sludge pond include waste activated sludge, sludge from the API separator and scum from dissolved air flotation. Supernatant from the sludge pond is pumped to the dissolved air flotation unit.

7. Cooling tower blowdown and neutralized regenerant wastewater are transported from the complex in the effluent sewer and are discharged. Other discharges from these options include uncontaminated runoff from the plant area, runoff from overburden storage and water from mine dewatering programs.

8. In the sediment pond, settling of suspended solids contained within the mine water occurs. If required, polymers are added to enhance fines settling. The mine water is subsequently discharged.

9. Filtrate from vacuum filtration of whole tailings is clarified and returned to hot water extraction (Figure 2-2).

Tables 4-16, 4-17 and 4-18 provide a summary of the sizes and capacities of the components of the wastewater treatment systems for Options 2, 5 and 12, respectively.

453 WASTEWATER TREATMENT SCHEME - SOLVENT EXTRACTION OPTIONS

For the solvent extraction options, the wastewater treatment scheme is similar in principle to the scheme for the tailings filtration options. The scheme is shown in Figure 3-9. Since a tailings pond is not required with solvent extraction, process wastewaters from all areas of the complex must be treated to a level suitable for recycle to the complex or for discharge.

The wastewater treatment scheme, described in items 1 to 8 in Section 452, is identical in concept to the treatment schemes for the solvent extraction options. Process wastewater flows in these options are greater than the tailings filtration options due to the increased cooling requirements and the wastewater from the Dravo Solvent Extraction Process.

Tables 4-19, 4-20 and 4-21 summarize the wastewater treatment components required in the solvent extraction options.

TABLE 4-16

Wastewater Treatment Systems
Option 2(1)

Component	Size(2)	Capacity
API Separator	3 channels: each 50 m x 5.1 m x 2 m	18 790 m^3/sd
Dissolved Air Flotation	3 flocculation chambers at 125 m^3 3 flotation chambers at 4 m x 18 m 2.5 m	20 230 m^3/sd
Activated Sludge	activated sludge unit at 4840 m^3 2 clarifiers of 24 m diameter	20 140 m^3/sd
Dual Media Filtration	2 filters: each 42 m^2	19 880 m^3/sd
Storm Pond	264 m x 264 m x 5 m	252 950 m^3
Recycle Pond	120 m x 120 m x 6 m	56 220 m^3
Sludge Pond	2 ponds: each 239 m x 239 m x 6 m	500 000 m^3
Sediment Pond	65 m x 65 m x 5 m	11 310 m^3
Sewage Treatment Plant	RBC Unit	1 140 m^3/sd

Notes: [1] Option 2 - Hot Water Extraction/Tailings Filtration/Fluid Coking/Gasification of Coke

[2] Pond dimensions include 1 m freeboard

TABLE 4-17

Wastewater Treatment Systems
Option 5(1)

Component	Size(2)	Capacity
API Separator	3 channels: each 50 m x 4.4 m x 2 m	15 440 m^3/sd
Dissolved Air Flotation	3 flocculation chambers at 108 m^3 3 flotation chambers at 4 m x 16 m 2.5 m	16 950 m^3/sd
Activated Sludge	activated sludge unit at 4217 m^3 2 clarifiers of 22 m diameter	16 870 m^3/sd
Dual Media Filtration	2 filters: each 37 m^2	16 640 m^3/sd
Storm Pond	264 m x 264 m x 5 m	252 950 m^3
Recycle Pond	113 m x 113 m x 6 m	49 080 m^3
Sludge Pond	2 ponds: each 228 m x 228 m x 6 m	456 200 m^3
Sediment Pond	61 m x 61 m x 5 m	9 570 m^3
Sewage Treatment Plant	RBC Unit	1 140 m^3/sd

Notes: [1] Option 5 - Hot Water Extraction/Tailings Filtration/H-Oil/Partial Oxidation of Pitch

[2] Pond dimensions include 1 m freeboard

TABLE 4-18

Wastewater Treatment Systems
Option 12(1)

Component	Size(2)	Capacity
API Separator	2 channels: each 37.5 m x 3.6 m x 1.5 m	4 760 m^3/sd
Dissolved Air Flotation	2 flocculation chambers at 66 m^3 2 flotation chambers at 3 m x 13.2 m x 2.0 m	5 220 m^3/sd
Activated Sludge	activated sludge unit at 1294 m^3 1 clarifier of 18 m diameter	5 180 m^3/sd
Dual Media Filtration	2 filters: each 11.2 m^2	5 110 m^3/sd
Storm Pond	190 m x 190 m x 5 m	126 470 m^3
Recycle Pond	73 m x 73 m x 5 m	14 920 m^3
Sludge Pond	2 ponds: each 155 m x 155 m x 6 m	196 800 m^3
Sediment Pond	31 m x 31 m x 5 m	1 470 m^3
Sewage Treatment Plant	RBC Unit	570 m^3/sd

Notes: [1] Option 12 - Hot Water Extraction/Tailings Filtration/H-Oil/Partial Oxidation of Pitch

[2] Pond dimensions include 1 m freeboard

TABLE 4-19

Wastewater Treatment Systems
Option 8(1)

Component	Size(2)	Capacity
API Separator	4 channels: each 50 m x 5.1 m x 2 m	26 920 m^3/sd
Dissolved Air Flotation	3 flocculation chambers at 200 m^3 3 flotation chambers at 4 m x 29 m x 3 m	28 910 m^3/sd
Activated Sludge	activated sludge unit at 6940 m^3 2 clarifiers of 29 m diameter	28 830 m^3/sd
Dual Media Filtration	4 filters: each 30 m^2	28 440 m^3/sd
Storm Pond	264 m x 264 m x 5 m	252 950 m^3
Recycle Pond	141 m x 141 m x 6 m	80 990 m^3
Sludge Pond	2 ponds: each 254 m x 254 m x 6 m	574 310 m^3
Sediment Pond	64 m x 64 m x 5 m	10 920 m^3
Sewage Treatment Plant	RBC Unit	1 140 m^3/sd

Notes: [1] Option 8 - Solvent Extraction/Fluid Coking/CO Boilers/Coke Boilers (FBC)
[2] Pond dimensions include 1 m freeboard

TABLE 4-20

Wastewater Treatment Systems
Option 9(1)

Component	Size(2)	Capacity
API Separator	4 channels: each 50 m x 5.1 m x 2 m	26 360 m^3/sd
Dissolved Air Flotation	3 flocculation chambers at 200 m^3 3 flotation chambers at 4 m x 29 m x 3 m	28 370 m^3/sd
Activated Sludge	activated sludge unit at 7073 m^3 2 clarifiers of 29 m diameter	28 290 m^3/sd
Dual Media Filtration	filter: 30.5 m^2	2 790 m^3/sd
Storm Pond	264 m x 264 m x 5 m	252 950 m^3
Recycle Pond	143 m x 143 m x 6 m	82 710 m^3
Sludge Pond	2 ponds: each 251 m x 251 m x 6 m	562,230 m^3
Sediment Pond	64 m x 64 m x 5 m	10 920 m^3
Sewage Treatment Plant	RBC Unit	1 140 m^3/sd

Notes:
[1] Option 9 - Solvent Extraction/Flexicoking/Flexigas Boilers
[2] Pond dimensions include 1 m freeboard

TABLE 4-21

Wastewater Treatment Systems
Option 14(1)

Component	Size(2)	Capacity
API Separator	2 channels: each 38 m x 4.8 m x 1.5 m	6 319 m^3/sd
Dissolved Air Flotation	2 flocculation chambers at 90 m^3 2 flotation chambers at 3 m x 19 m x 2 m	6 670 m^3/sd
Activated Sludge	activated sludge unit at 1674 m^3 1 clarifier of 20 m diameter	6 628 m^3/sd
Dual Media Filtration	2 filters: each 14.1 m^2	6 537 m^3/sd
Storm Pond	190 m x 190 m x 5 m	126 470 m^3
Recycle Pond	81 m x 81 m x 5 m	19 215 m^3
Sludge Pond	2 ponds: each 159 m x 159 m x 6 m	209 268 m^3
Sediment Pond	32 m x 32 m x 5 m	1 636 m^3
Sewage Treatment Plant	RBC Unit	570 m^3/sd

Notes:
[1] Option 14 - Solvent Extraction/Flexicoking/Flexigas Boilers
[2] Pond dimensions include 1 m freeboard

454 WASTEWATER TREATMENT SCHEME - DIRECT COKING OPTIONS (Options 10 and 15)

A portion of the wastewater treatment scheme for the direct coking option is similar to the tailings filtration options and is described in items 1 to 8 in Section 452. The scheme is presented in Figure 3-11. Wastewater flows within the process waste sewer are less than in the tailings filtration options (approximately 50%), however, the cooling water requirements are greater. A major additional treatment unit is required in the direct coking options for reduction in phenols and fatty acids within the sour water from the direct coking process.

It has been reported by the licensor that the sour water contains 900 mg/L phenols and 3000 mg/L fatty acids. The fatty acids are steam volatile carboxylic acid defined as acetic acid. The main components of the fatty acids are the benzonic, butanoic and acetic acids.

A high rate biological process is assumed for reduction of the phenol load with waste sludge from the system directed to the sludge pond, after thickening to 3% solids by weight. With successful acclimatization of the biological mass, sufficient phenol reduction is feasibile to permit recycle of the treated sour water for spent sand quenching and moistening. The significant fatty acid load in this waste stream is a cause for concern. It has been assumed that the fatty acids are removed prior to biological treatment in a dissolved air flotation unit operating in the flocculation/flotation mode. Scum from the flotation unit is pumped to the sludge pond. The volume contribution of scum coupled with waste sludge from phenol removal system and other waste sludge create tremendous volumes of sludge. As a result, the required sludge ponds are extremely large. For Option 10, it has been assumed that the sludge pond are made up of four cells with a total capacity to store thickened sludges for 5 years. Hence, removal and disposal of sludge from the ponds is required.

Upon further clarification of the nature of the fatty acids in the sour water stream, other alternatives for handling this material can be considered. These include separation and recycle back to the plant or utilization off-site as a feedstock. Nevertheless, the handling of fatty acids within the scheme established for the direct coking options is a major concern.

Tables 4-22 and 4-23 provide a summary of the wastewater treatment components required in the direct coking options.

TABLE 4-22

Wastewater Treatment Systems
Option 10(1)

Component	Size(2)	Capacity
API Separator	3 channels: each 38 m x 3.7 m x 1.5 m	8 040 m^3/sd
Dissolved Air Flotation (DAF)	2 flocculation chambers at 160 m^3 3 flotation chambers at 4 m x 12 m x 3 m	11 210 m^3/sd
Activated Sludge	activated sludge unit at 3622 m^3 2 clarifiers of 18 m diameter	11 150 m^3/sd
Dual Media Filtration	2 filters: each 24 m^2	11 000 m^3/sd
Storm Pond	227 m x 227 m x 5 m	183 960 m^3
Recycle Pond	105 m x 105 m x 5 m	34 440 m^3
Sludge Pond	ponds: each 484 m x 480 m x 6 m	44 000 000 m^3
Sediment Pond	62 m x 62 m x 5 m	10 100 m^3
Biox Unit	Biox unit at 1735 m^3 DAF: 2 flocculation chambers at 85 m^3 2 flotation chambers at 3 m x 17 m x 2.5 m Sludge thickener at 690 m^3/d of sludge	10 670 m^3/sd
Biox Storage Pond	65 m x 65 m x 65 m	8 610 m^3
Sewage Treatment Plant	RBC Unit	1 140 m^3/sd

Notes: [1] Option 10 - Direct Coking
[2] Pond dimensions include 1 m freeboard

TABLE 4-23

Wastewater Treatment Systems
Option 15(1)

Component	Size(2)	Capacity
API Separator	2 channels: each 30 m x 3.1 m x 1.5 m	3 120 m^3/sd
Dissolved Air Flotation (DAF)	2 flocculation chambers at 60 m^3 2 flotation chambers at 3 m x 14 m x 3 m	4 120 m^3/sd
Activated Sludge	activated sludge unit at 1023 m^3 1 clarifier of 16 m diameter	4 090 m^3/sd
Dual Media Filtration	1 filter: 17.2 m^2	4 040 m^3/sd
Storm Pond	164 m x 164 m x 5 m	91 980 m^3
Recycle Pond	67 m x 67 m x 5 m	12 030 m^3
Sludge Pond	2 ponds: each 264 m x 264 m x 6 m	600 000 m^3
Sediment Pond	32 m x 32 m x 5 m	1 520 m^3
Biox Unit	Biox unit at 260 m^3 DAF: 1 flocculation chamber at 25 m^3 1 flotation chamber at 3 m x 5 m x 3 m	1 600 m^3/sd
Biox Storage Pond	36 m x 36 m x 3 m	1 290 m^3
Sewage Treatment Plant	RBC Unit	540 m^3/sd

Notes: [1] Option 15 - Direct Coking
[2] Pond dimensions include 1 m freeboard

455 TREATMENT SYSTEM COMPONENTS - SIZING BASIS

Factors which have been used for the determination of treatment component sizes are summarized in this section.

.1 Storm Pond

The storm pond provides storage for in-plant runoff flows in excess of the capacities of downstream treatment and pumping facilities. It is sized to provide storage of excess runoff during the spring melt period (assumed to occur equally over 30 days) plus runoff from the 1 in 10 year 24 hour storm. Water from the storage pond is returned to the inlet of the API separator for treatment over a 30 day period.

.2 API Separator

Wastewater which normally contains oil and grease or which has the potential to be contaminated with hydrocarbons is routed to the API separator. Within the unit, free oil rises to the surface in the separator channels and is skimmed off into oil recovery tanks. Suspended solids are also separated in the unit. Factors which affect the oil removal efficiency of API separators include the specific gravity of the oil in the wastewater, rate of rise of oil globules, temperature, and channel dimensions. The separators have been sized for severe conditions using standard design factors (channel depth to width ratio, vertical velocity to horizontal velocity ratio, maximum channel dimensions, etc.).

It is assumed that 70% of the oil and grease discharged to the process waste sewer is removed in the separator and returned to the plant. Further, 50% of the suspended solids are removed. Sludge from the separator which contains 7% solids by weight is pumped to the sludge pond.

.3 Sludge Ponds

Alum sludge from the potable water treatment plant, digested sewage sludge from the sewage treatment plant, sludge from the API separator and waste activated sludge make up the input streams to the sludge ponds. Thickening of the sludge to 25% solids by weight is assumed to occur by the combined actions of sedimentation and consolidation, enhanced by freeze-thaw mechanisms. Supernatant is removed from the sludge ponds during the frost-free months and is pumped to the effluent pond in the tailings pond options (1, 3, 4, 6, 7, 11 and 13). In all other options, the supernatant is returned to the dissolved air flotation unit.

With the exception of Option 10, the sludge ponds provide sludge storage capacity for 25 years of operation. In Option 10, five years of storage is provided.

.4 Effluent Pond

The effluent pond receives efluent from the API separator, supernatant from the sludge ponds and the effluent sewer discharge. The pond is sized to provide 24 hour storage for the above flows. Wastewater from the effluent pond is pumped to the tailings pond.

.5 Recycle Pond

A recycle pond is provided in all options. It receives discharge from the recycle sewer and provision is made to divert part or all of the drainage ditch water, if the quality proves suitable, to the recycle pond. In Options 2, 5, 8, 9, 10, 12, 14 and 15, filtered effluent from dual media filtration is also pumped to the recycle pond.

The pond is lined and sized for 72 hours storage capacity. Effluent from the recycle pond is pumped to the plant for reuse.

.6 Reclaim Pond

A reclaim pond is provided in all the tailings pond options (1, 3, 4, 6, 7, 11 and 13). The main purpose of the pond is to "age" or further polish the water reclaimed from the tailings pond. It is sized to provide 48 hours storage for reclaim water from the tailings pond plus other make-up water to hot water extraction. Water from the reclaim pond is returned to the extraction plant.

.7 Dissolved Air Flotation

The dissolved air flotation unit is provided in options (2, 5, 8, 9, 10, 12, 14 and 15) for secondary oil removal and suspended solids reduction. The system operates in combination with flocculation to reduce the total oil content by 85 to 99% and suspended solids by 80 to 93% (Environmental Protection Agency 1980). Provision has been made for two chemical feed systems using alum and polymer to supplement the air flotation process.

Specific design parameters for the dissolved air flotation system are summarized below:

Overflow rate		$1.7\ L/s/m^2$
Rise velocity		0.10 m/min
Retention time		20 min.
Recycle		20%
Feed rate:	Alum	100 mg/L
	Polymer	10 mg/L

Air injection	0.93 m^3/1000 m^3

Scum from dissolved air flotation is pumped to the sludge pond and the effluent is directed to the activated sludge unit for further treatment.

.8 Activated Sludge System

Information on the organic load within the process wastewater stream is limited. Nevertheless, removal of BOD and COD is required. The biochemical oxygen demand of the wastewater entering the activated sludge system has been assumed to be 250 mg/L.

The following parameters were used in sizing the activated sludge system:

Detention time	6 hours
Return activated sludge	30%
Air	60 m^3/kg BOD
Clarifier overflow rate	30 $m^3/d/m^2$

Excess sludge from the clarifier is pumped to the sludge pond and the effluent is directed to dual media filters.

.9 Dual Media Filtration

Filtration of the wastewater stream is provided to ensure further suspended solids removal. The resultant treated wastewater stream will have a total suspended solids concentration less than 0.5 mg/L.

The following design parameters are used for sizing the filtration system:

Filtration rate	235 $m^3/d/m^2$
Backwash rate	4%

For flows less than 19 000 m^3/d at least two filters are provided. Filter backwash water is returned to the dissolved air flotation unit and the filtrate is pumped to the recycle pond for reuse in the plant.

.10 Sediment Pond

In all options without a tailings pond, mine drainage from the mining operation is discharged to a sediment pond for settling of fines. A 48 hour retention is provided and provision has been made for a polymer feed system if necessary. Effluent from the sediment pond will be discharged to the environment.

.11 Sewage Treatment Plant

Sanitary sewage from the work force in the mining area, permanent camp, cafeteria, administrative and maintenance areas is treated in a Rotating Biological Contactor unit, disinfected and discharged into the effluent sewer in the tailings pond options or process waste sewer in all other options. Sludge from the treatment plant is aerobically digested and discharged to the sludge sewer.

For the purpose of this study, a work force of 2500 people has been assumed for the 20 000 m^3/d options and 1250 people for the 3000 m^3/d options. A per capita waste discharge of 450 L is assumed.

.12 Biox Unit (including clarifier and storage pond)

In the direct coking options (Options 10 and 15), sour water is produced which is high in fatty acids and phenols. As discussed in Section 454, the nature of the fatty acids is not known and therefore a treatment using dissolved air flotation to remove fatty acids and biox unit (high rate activated sludge) to degrade phenols is proposed.

The units have been sized using the following:

Dissolved Air Flotation:

Overflow Rate	1.7 L/s/m^2
Rise Velocity	0.1 m/min
Retention Time	20 min
Alum feed Rate	100 mg/L
Polymer feed Rate	10 mg/L
Recycle	20%
Air injection	0.93 m^3/1000 m^3
Fatty Acids Removal	99%
Sludge concentration	3%

Biox Unit:

Detention time	2 - 4 hours
Recycle Ratio	30%
Phenol Oxygen demand	1.7 kg O_2/kg phenol
Excess sludge	1.1 kg/kg BOD
Clarifier overflow	30 m^3/d/m^2
Sludge concentration	3%

Fatty acids from the dissolved air flotation unit and excess sludge from the clarifier/thickener are discharged to the sludge pond. The clarifier overflow is discharged to a storage pond with 24 hour retention time. The purpose of the pond is to minimize the fluctuation in the effluent quality in case of clarifier or biox unit upset. Effluent from the pond is pumped to extraction for reuse.

4.6 SOLID WASTE DISPOSAL

Solid waste streams from the 15 optional mining oil sands complexes are identified in the pollutant flow diagrams presented in Part 3. These wastes can be broadly categorized as follows:

1. those solids which are transported off-site for utilization or regeneration;
2. overburden materials from the oil sands mining operation;
3. rejects, dry tailings and spent sand; and
4. other solid wastes from upgrading, utilities and offsites.

Solid wastes, other than those materials transported off-site, are disposed of in the mined-out area of the oil sands mining operation. The deposition of these waste materials is a planned program that forms an integral part of the overall mine reclamation program. Reclamation of the mined-out area occurs continuously over the life of mining operation. Mine reclamation is essentially a selective material handling process aimed at returning the mine site to an environmental acceptable condition compatible with the ultimate land use. Accordingly, it must be planned, engineered and executed in the same manner as the mining operation. Apart from constraints placed on the solid waste disposal method by the mining operation itself, the presence of an in-pit tailings pond in the mined-out area decreases available space for solid waste disposal. Further, leakage from the tailings pond must be diverted from the solid waste disposal operation.

Subsoil disposal in the mine presents no significant environmental concerns. On the other hand, muskeg remains relatively wet in spite of the dewatering program during site preparation stages and drainage during stockpiling. Accordingly, the muskeg is incorporated into the preparation of the final surface of the reclaimed area of the mine.

Dry tailings from the tailings filtration and solvent extraction options and spent sand from the direct coking options are conveyed back to the mine via conveyors. As the majority of these materials originate in the mined oil sands, there are no specific concerns with the disposal in the mine. Their volumes are substantial, hence a dedicated fleet of equipment in continuous operation would handle and spread the material as it is received in the mine. The spent sand from the direct coking operation also contains fly ash from flue gas treatment (part of the direct coking process) and heavy metals from the upgrading which takes place within the process. As a result, leaching of heavy metals may be of concern; however, the spent sand also contains significant quantities of gypsum and unreacted lime which may tend to limit the mobility of metals.

The dry tailings from tailings filtration and solvent extraction options and spent sand from the direct coking options may be utilized in part to form cells within the reclamation area for the disposal of other solid wastes from upgrading utilities and offsites. These materials which include fines and char from Flexicoking, slag and char from residue gasification, fly ash and bottom ash from CO and utility boilers, spent bed materials from fluidized bed boilers and solid waste incinerator ash are transported to the mine by truck and are dumped directly into the aforementioned cells or other specially prepared areas. These residue materials contain metals in a concentrated form and, as a result, must be contained. Accordingly, the permeability of the base within the special prepared areas should be in the order of 10^{-7} cm/sec, runoff should be diverted from the disposal area and cover material applied periodically to reduce infiltration. Further, the waste may have to be compacted upon placement.

Other materials which may be periodically disposed of in the mine include spent catalysts from the Claus sulphur recovery process and from the hydrotreaters in secondary upgrading. The nature of these materials is unknown, but it is expected that leaching of metals and organics may occur if the materials are handled and disposed of in an uncontrolled manner.

In summary, solid waste materials which are disposed of in the mined-out area of the mining operation should present few significant environmental concerns provided:

1) their disposal in the mined-out area is part of the overall mine reclamation program;

2) the disposal program is governed by site-specific hydrogeological factors which will determine the remedial measures required to protect groundwater;

3) a monitoring program is established early in the life of the mine to detect migration of contaminants from the disposal area;

4) solid waste containing leachable metals and/or organics are disposed of in cells or prepared areas; and

5) runoff is diverted from the disposal area.

However fugitive dust emissions from the conveying and disposal of dry tailings can present a waste management concern, particularly in windy weather conditions. Such fugitive emissions are, however, impossible to quantify.

Solid wastes which are not disposed of in the mined-out area include sulphur, net coke or pitch, and spent catalysts from the H-Oil primary upgrading process. Sulphur is sold as a byproduct and is transported off-site for utilization. Net coke or pitch, those residuals which are in excess of the utility requirements, are stored in lined and dyked areas for possible reuse. It has been assumed that spent catalysts from the H-Oil reactor are transported off-site for clean-up and regeneration.

4.7 LONG-TERM WASTE MANAGEMENT RAMIFICATIONS

The design life of mining oil sands plants is about 25 to 30 years. In practice, provided there are sufficient mineable reserves of oil sands, process changes to upgrade the plant and improve efficiencies will result in these plants operating for longer then their design life. The volumes of wastes produced by a mining oil sands complex, coupled with their long operating life, indicates the need to examine the long-term ramifications of a plant's waste management systems. In addition, the complex will eventually be turned down and the mine and plant site cleaned up and reclaimed during decommissioning activities.

During the operating life of the plant, emissions will be discharged to the environment, with or without treatment. The majority of gaseous emissions will be treated prior to venting to atmosphere. However, the long-term impact of these emissions on the environment must be assessed, particularly in light of future oil sands developments along the Athabasca River valley. If these emissions are found to be negatively impacting the environment, regulatory agencies may require both existing and any future plants to meet more stringent emission limits than those already in place or currently proposed. This will result in either substantially increased costs for waste management facilities or the adoption of process technologies which emit lesser amounts of wastes.

Of the 15 options considered in this study, seven disposed of their tailings in a tailings pond. The presence of a tailings pond significantly reduces the volumes of wastewater discharged to the environment. However, even with a tailings pond, there is the possibility of spills or leaks resulting in the discharge of partially treated or untreated wastewater to the environment. Concern has already been expressed about the long-term effects of mining oil sands plants on the Athabasca River, from the standpoint of both wastewater discharges to the river and water abstractions. As in the case of gaseous emissions, increased government regulations may result from concerns regarding the effects of these plants on the Athabasca River.

The largest volumes of solid waste from a mining oil sands complex are the tailings. Depending on the extraction process, these tailings can be handled wet, discharged into a tailings pond, or handled dry. However, irrespective of the method of handling the tailings, over the operating life of a plant, significant quantities of tailings will be disposed of in the mined-out area of the mine. Similarly, other solid wastes, some containing high concentrations of heavy metals, will also be disposed of in the mine area. Reclamation of the mined-out area of the mine will continue throughout the plant's operating life. An integral part of any reclamation activities will therefore be a monitoring program to ensure that contaminants leached from the tailings and other solid wastes do not enter the local groundwater system.

For the seven options with a tailings pond, after approximately eight years of plant operation there is sufficient mined-out area in the mine for use as an in-pit tailings pond. Following plant decommissioning, the in-pit tailings pond would be reclaimed as part of the long-term mine reclamation program and would include the establishment of a vegetative cover. Because of the nature of the sludge fraction within the external tailings pond, it would most likely remain as a permanent body of water. The surface and side slopes of the dykes of the external pond would be reclaimed with the establishment of a vegetative cover (an ongoing process throughout the life of the oil sands project) and a long-term monitoring program would be established.

With respect to plant turndown and decommissioning, the following activities associated with waste management are envisaged:

- reclamation of tailings ponds, as outlined above;
- reclamation of sludge ponds and necessary monitoring to determine the integrity of the pond liners;
- clean-up and reclamation of areas used to store coke, sulphur, other solid wastes and sludges;
- an extensive monitoring program to determine the contamination of soils, overburden, surface and groundwaters on the plant site;
- as a result of the monitoring program, the initiation of the necessary clean-up and reclamation activities to ensure the plant site is returned to an environmentally acceptable condition.

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- as a result of the monitoring program, the initiation of the necessary clean-up and reclamation activities to ensure the plant site is returned to an environmentally acceptable condition.

PART 5

MATERIAL BALANCES

PART 5 - MATERIAL BALANCES

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5-14	Sulphur Balance - Option 14	5-32
5-15	Sulphur Balance - Option 15	5-34
5-16	Water Management Scheme - Option 1	5-36
5-17	Water Management Scheme - Option 2	5-38
5-18	Water Management Scheme - Option 3	5-40
5-19	Water Management Scheme - Option 4	5-42
5-20	Water Management Scheme - Option 5	5-44
5-21	Water Management Scheme - Option 6	5-46
5-22	Water Management Scheme - Option 7	5-48
5-23	Water Management Scheme - Option 8	5-50
5-24	Water Management Scheme - Option 9	5-52
5-25	Water Management Scheme - Option 10	5-54
5-26	Water Management Scheme - Option 11	5-56
5-27	Water Management Scheme - Option 12	5-58
5-28	Water Management Scheme - Option 13	5-60
5-29	Water Management Scheme - Option 14	5-62
5-30	Water Management Scheme - Option 15	5-64

5.1 CONVERSION EFFICIENCIES

The extraction of bitumen from oil sands and subsequent upgrading of recovered bitumen are processes which vary in efficiency with the oil sands quality and processes selected. In order to determine normal flow rates for gaseous, liquid and solid waste streams for each of the selected options, a stream day synthetic crude production rate and oil sands bitumen content have been established. In all options, the bitumen content of the oil sands is 11.5% by weight, of which 4.9% is sulphur, and 51% is pitch (boiling point greater than 425°C).

Conversion efficiencies for each extraction and upgrading method were obtained from literature sources or directly from process licensors. The established data and process conversion efficiencies were then used to compute the oil sands feed, mine size and mining rate, and process-related waste stream flows. The following summarizes the efficiencies used in this study:

1. Rejects removed by screening prior to extraction reduces the bitumen feed to extraction by 0.5% (0.52% in Options 10 and 15).

2. Recovery of bitumen through froth removal and middlings treatment in hot water extraction is 92.5% efficient and dilution centrifuging of the froth recovers 98% of bitumen from primary extraction (Cameron Engineers Inc. 1975, Alsands Project Group 1978). Bitumen which is not recovered is discharged with the tailings.

3. In Options 2, 5 and 12, where vacuum filtration of whole tailings is practised, it is expected that some bitumen from the tailings would be recovered. Since data is not available to confirm the bitumen recovery from the filter, the overall extraction efficiency was not changed.

4. Bitumen recovery from the Dravo Solvent Extraction Process was established at 95.7% by weight (Baczewski pers. comm.).

5. The overall conversion of bitumen to synthetic crude products in the Lurgi Direct Coking Process is 73.3% by weight (Weiss pers. comm.).

6. In all cases it is assumed that whole bitumen is charged to the primary upgrading reactor. Exceptions to this are Options 6 and 13 (CANMET) where atmospheric and vacuum distillation precedes the CANMET unit, with vacuum residuum (boiling point greater than 524°C) directed to the hydrocracking reactor and in Options 10 and 15 where direct coking of oil sands generates intermediate product streams.

7. In the fluid coking and Flexicoking options, approximately 70% of the whole bitumen feed to upgrading is recovered as synthetic crude products (Egglestone and Wise 1976).

8. In the H-Oil and CANMET processes, it is assumed that 90% conversion of the bitumen fraction boiling over 524°C is recovered (Johnson et al. 1977, Chambers et al. 1982).

9. Product yields from the Eureka upgrading process relative to Athabasca bitumen are not specified in available literature, however, a conversion efficiency of 73% was estimated from data on the upgrading of Middle East residues (Aiba et al. 1981) supplemented with in-house information and recent literature on the upgrading of Athabasca bitumen (Aiba et al. 1982).

10. Naphtha diluent for froth treatment in the hot water extraction options and solvent required for the solvent extraction options are made up from upgrading liquid product streams.

Table 5-1 summarizes the bitumen feed to extraction, the conversion efficiencies of the selected extraction and upgrading processes, and the synthetic crude production rate for each option. The conversion efficiencies are provided to illustrate the assumptions required to quantify waste streams. Care should be exercised in comparing the information in Table 5-1 from option to option since it was obtained from a variety of literature sources with varying conditions.

5.2 SULPHUR BALANCE

The disposition of sulphur within the oil sands complexes is computed for each option. In all options except Options 10 and 15, the majority of the sulphur contained within the bitumen feed is recovered as elemental sulphur within the sulphur plant. The quantity of sulphur recovered as elemental sulphur varies from about 70% to 96% of the sulphur input to upgrading. The higher percentages are achieved in the Flexicoking options and those options where coke or pitch residues are gasified. Prior to the use of the low joule flexigas and medium joule gasification product as utility fuels, acid gases are removed by amine absorption and are routed to the sulphur plant for conversion to elemental sulphur. In Options 10 and 15, approximately 55% of the sulphur input is removed as gypsum within the direct coking spent sand.

CO boilers, coke boilers and pitch boilers are the major sources of sulphur atmospheric emissions. As described in Section 4.4, desulphurization of boiler flue gases is achieved by ammonia scrubbing. Sulphur removed in the flue gas desulphurization process is in the form of an ammonia bisulphite/ammonia sulphite solution.

TABLE 5-1

Bitumen to Synthetic Crude - Conversion Efficiencies

Option No.	Bitumen Feed(1) to Extraction	Conversion Efficiencies % wt			Synthetic Crude(2) Production
		Extraction	Upgrading	Overall	
1	29535	90.16	70.59	63.64	20000
2	29535	90.16	70.59	63.64	20000
3	29535	90.16	70.58	63.64	20000
4	24985	90.16	83.44	75.23	20000
5	24985	90.16	83.44	75.23	20000
6	23680	90.16	88.05	79.39	20000
7	28505	90.16	73.14	65.95	20000
8	28020	95.70	70.11	67.10	20000
9	28020	95.70	70.11	67.10	20000
10	23460	73.30(3)	-	73.30	20000
11	4430	90.16	70.59	63.64	3000
12	3750	90.16	83.44	75.23	3000
13	3550	90.16	88.05	79.39	3000
14	4205	95.70	70.11	67.10	3000
15	3520	73.30(3)	-	73.30	3000

Notes: [1] tonnes per stream day

[2] cubic metres per stream day

[3] includes upgrading

The remaining major sulphur-containing stream is the synthetic crude product. Product sulphur compositions range from 0.18% to 0.26% for the selected options.

Tables 5-2 to 5-16 provide a summary of the sulphur balance for each option. Figures 5-1 to 5-15 illustrate the distribution of major sulphur-containing streams through upgrading and utilities for each option.

5.3 WATER BALANCE

The water supply for the oil sands complexes is made up of raw water from the Athabasca River which is supplied to various uses in the plants from the raw water pond. In the options utilizing hot water extraction, the bulk of the hot water requirement for extraction is water reclaimed from the tailings pond, or filtrate from tailings filtration.

Major water inputs and outputs for each option are tabulated in Tables 5-17 to 5-31, on an annual basis. The in-plant water management scheme is determined by the overall water requirements for extraction, upgrading, utilities and offsites and by apparent water quality constraints of various processes. Water management schemes for each option are shown in Figures 5-16 to 5-30. The in-plant water management schhmes do not include discharges to natural drainage courses or those wastewaters which are internally recycled (not discharged to sewer system).

The use of recycled water within each option has not been identified in detail since individual process water quality constraints were not established. It is assumed, however, that water from the raw water pond is the water supply for the potable water treatment plant and for the utilities water treatment plant which supplies boiler feedwater. Therefore, the uses of recycled water may include make-up to the extraction plant, make-up to product gas scrubbing systems, make-up to flue gas scrubbing systems, water supply to clean-up and washdown systems, make-up to slurrying and sluicing systems, and possibly, make-up to the cooling water system. A detailed chemical balance is required to confirm the disposition of recycled water in each option.

In the options with a tailings pond, it is assumed that no dilution of the wet tailings is required prior to pumping the slurry to the tailings pond. If dilution should be required to reduce the solids content, reclaim water from the tailings pond would be used for this purpose, thus increasing the raw water intake requirements for these options.

TABLE 5-2

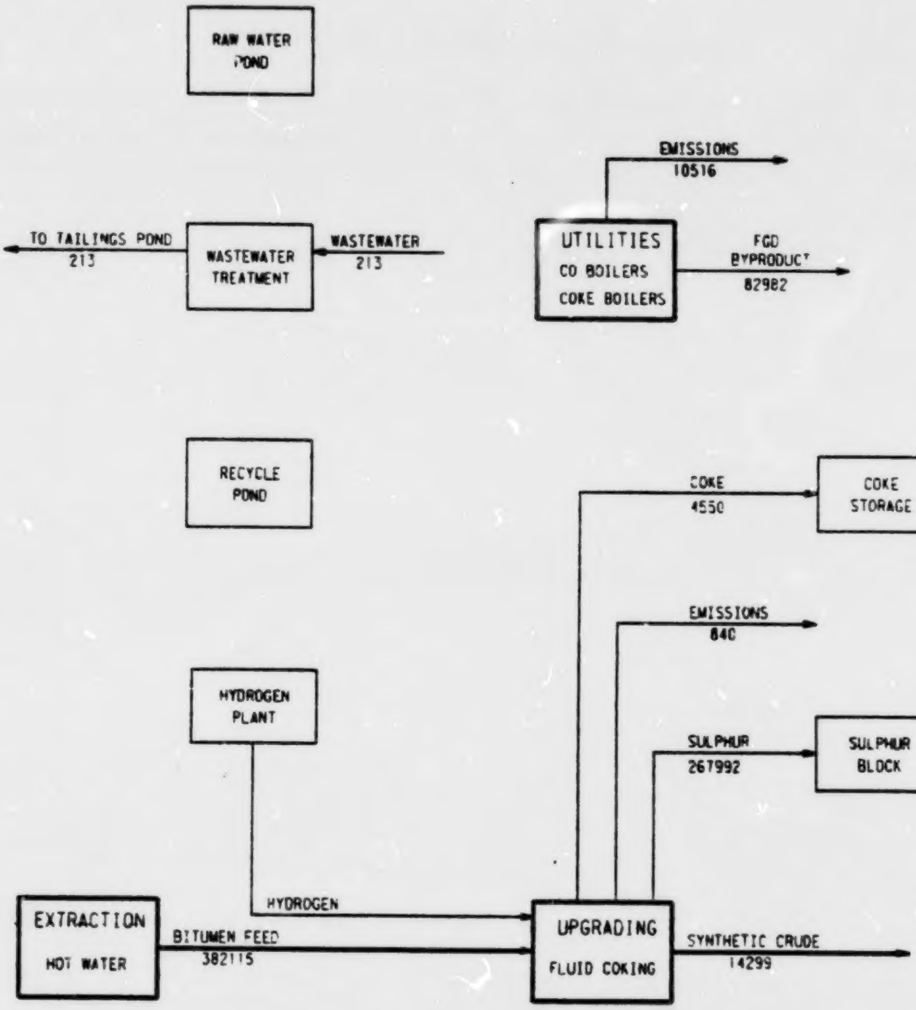
Sulphur Balance - Option 1(1)

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	382 115	100.00
OUTPUT		
Sulphur Block	267 992	70.13
Emissions		
Sulphur Plant	267	0.07
Fired Heaters	563	0.15
CO Boilers	2 417	0.62
Coke Boilers	8 039	2.10
Superheaters	60	0.02
Flare(2)	10	0.00
Liquids		
Wastewater	213	0.05
FGD Byproduct	82 982	21.72
Other Solids		
Net Coke	4 550	1.19
Syncrude Product	14 299	3.74
Total Output	381 392	99.81

Note: [1] Option 1 - Hot Water Extraction/Fluid Coking/CO and Coke Boilers

[2] This is a design figure. Operating data indictes tht the actual amount of sulphur flared may be considerably higher.

SULPHUR BALANCE


RAW WATER POND
EMISSIONS
10516
TO TAILINGS POND
213
WASTEWATER TREATMENT
WASTEWATER
213
UTILITIES
CO BOILERS
COKE BOILERS
FGD BYPRODUCT
82982
RECYCLE POND
COKE
4550
COKE STORAGE
EMISSIONS
840
HYDROGEN PLANT
SULPHUR
267992
SULPHUR BLOCK
HYDROGEN
EXTRACTION
HOT WATER
BITUMEN FEED
382115
UPGRADING
FLUID COKING
SYNTHETIC CRUDE
14299

UNITS: TONNES PER YEAR

FIGURE 5-1

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 1 HOT WATER EXTRACTION/FLUID COKING/
CO & COKE BOILERS

MONENCO CONSULTANTS LIMITED

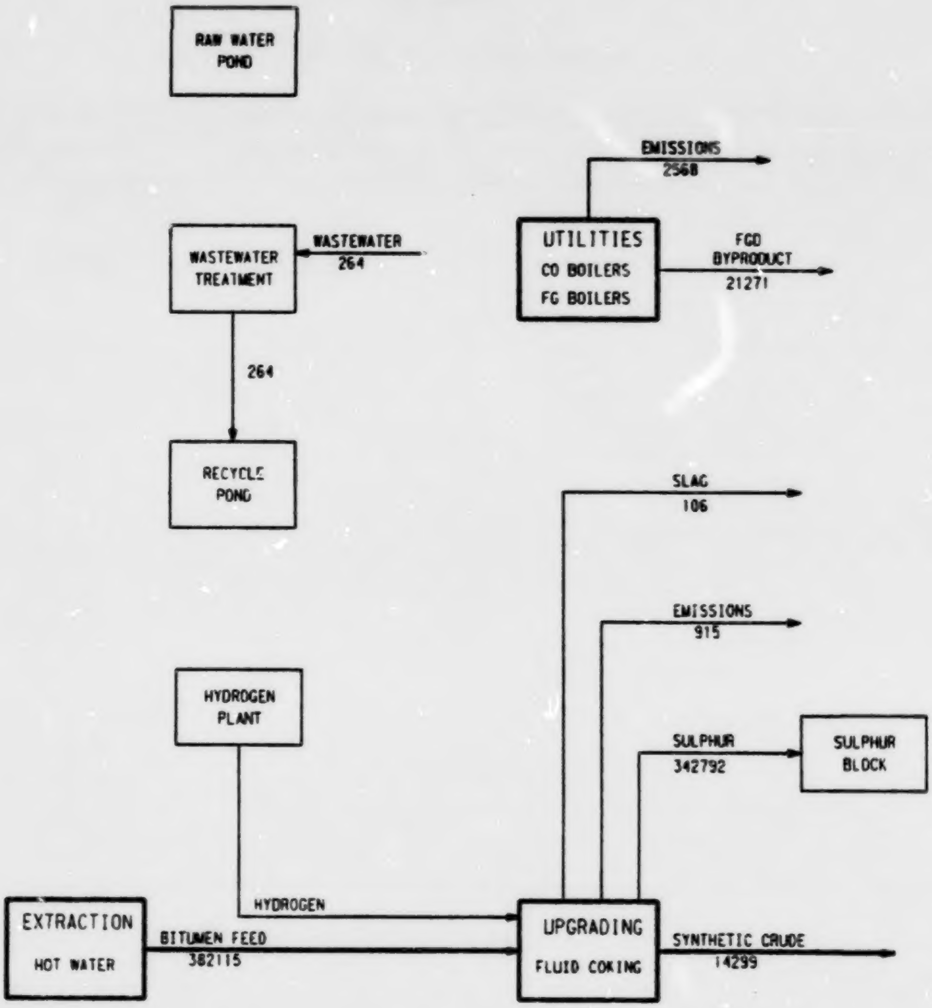
TABLE 5-3

Sulphur Balance - Option 2(1)

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	382 115	100.00
OUTPUT		
Sulphur Block	342 792	89.71
Emissions		
Sulphur Plant	342	0.09
Fired Heaters	563	0.15
CO Boilers	2 417	0.62
PG Boilers	97	0.03
Superheaters	54	0.01
Flare	10	0.00
Liquids		
Wastewater	264	0.07
FGD Byproduct	21 271	5.57
Other Solids		
Slag	106	0.03
Syncrude Product	14 299	3.74
Total Output	382 215	100.03

Note: [1] Option 2 - Hot Water Extraction/Tailings Filtration/Fluid Coking/Gasification of Coke

SULPHUR BALANCE


RAW WATER POND
WASTEWATER TREATMENT
WASTEWATER
264
264
RECYCLE POND
UTILITIES
CO BOILERS
FG BOILERS
EMISSIONS
2568
FGD BYPRODUCT
21271
SLAG
106
EMISSIONS
915
HYDROGEN PLANT
SULPHUR
342792
SULPHUR BLOCK
EXTRACTION
HOT WATER
HYDROGEN
BITUMEN FEED
382115
UPGRADING
FLUID COKING
SYNTHETIC CRUDE
14299

UNITS: TONNES PER YEAR

FG - MEDIUM JOULE FUEL GAS

FIGURE 5-2

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION 2 HOT WATER EXTRACTION/TAILINGS
FILTRATION/FLUID COKING/
GASIFICATION OF COKE
MONENCO CONSULTANTS LIMITED

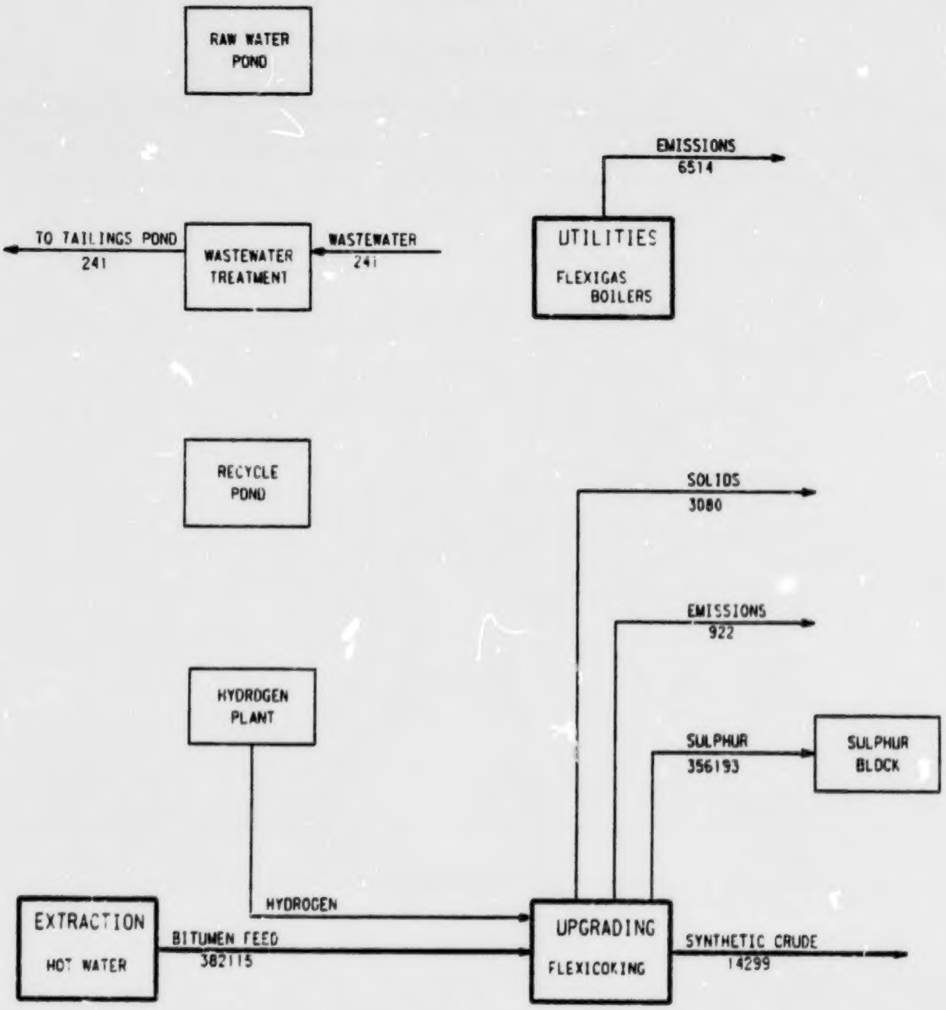
TABLE 5-4

Sulphur Balance - Option 3(1)

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	382 115	100.00
OUTPUT		
Sulphur Block	356 193	93.22
Emissions		
Sulphur Plant	343	0.09
Fired Heaters	569	0.15
Flexigas Boilers	6 514	1.71
Flare	10	0.00
Liquids		
Wastewater	241	0.06
Other Solids		
Char	3 077	1.07
Fines	3	0.00
Syncrude Product	14 299	3.74
Total Output	381 249	99.77

Note: [1] Option 3 - Hot Water Extraction/Flexicoking/Flexigas Boilers

SULPHUR BALANCE


RAW WATER POND
TO TAILINGS POND
241
WASTEWATER TREATMENT
WASTEWATER
241
EMISSIONS
6514
UTILITIES
FLEXIGAS BOILERS
RECYCLE POND
SOLIDS
3080
EMISSIONS
922
HYDROGEN PLANT
SULPHUR
356193
SULPHUR BLOCK
HYDROGEN
EXTRACTION
HOT WATER
BITUMEN FEED
382115
UPGRADING
FLEXICOKING
SYNTHETIC CRUDE
14299

UNITS: TONNES PER YEAR

FIGURE 5-3

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 3 HOT WATER EXTRACTION/FLEXICOKING/
FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED

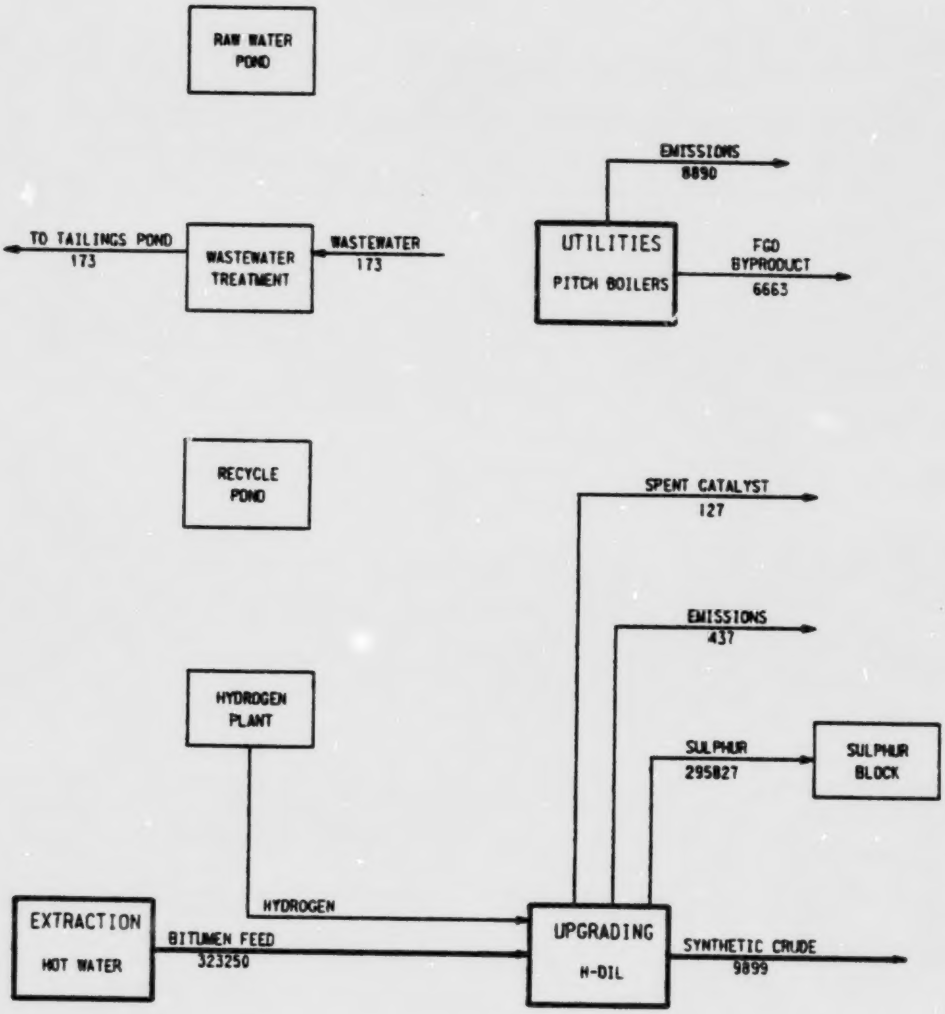
TABLE 5-5

Sulphur Balance - Option 4(1)

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	323 250	100.00
OUTPUT		
Sulphur Block	295 827	91.52
Emissions		
Sulphur Plant	293	0.09
Fired Heaters	129	0.04
Pitch Boilers	8 890	2.75
Flare	15	0.00
Liquids		
Wastewater	173	0.05
FGD Byproduct	6 663	2.06
Other Solids		
Spent Catalyst	127	0.04
Syncrude Product	9 899	3.06
Total Output	322 016	99.62

Note: [1] Option 4 - Hot Water Extraction/H-Oil/Pitch Boilers

SULPHUR BALANCE


RAW WATER POND
EMISSIONS
8890
TO TAILINGS POND
173
WASTEWATER TREATMENT
WASTEWATER
173
UTILITIES
PITCH BOILERS
FGD BYPRODUCT
6663
RECYCLE POND
SPENT CATALYST
127
EMISSIONS
437
HYDROGEN PLANT
SULPHUR
295827
SULPHUR BLOCK
HYDROGEN
EXTRACTION
HOT WATER
BITUMEN FEED
323250
UPGRADING
H-OIL
SYNTHETIC CRUDE
9899

UNITS: TONNES PER YEAR

FIGURE 5-4

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 4 HOT WATER EXTRACTION/
H-OIL/PITCH BOILERS

MONENCO CONSULTANTS LIMITED

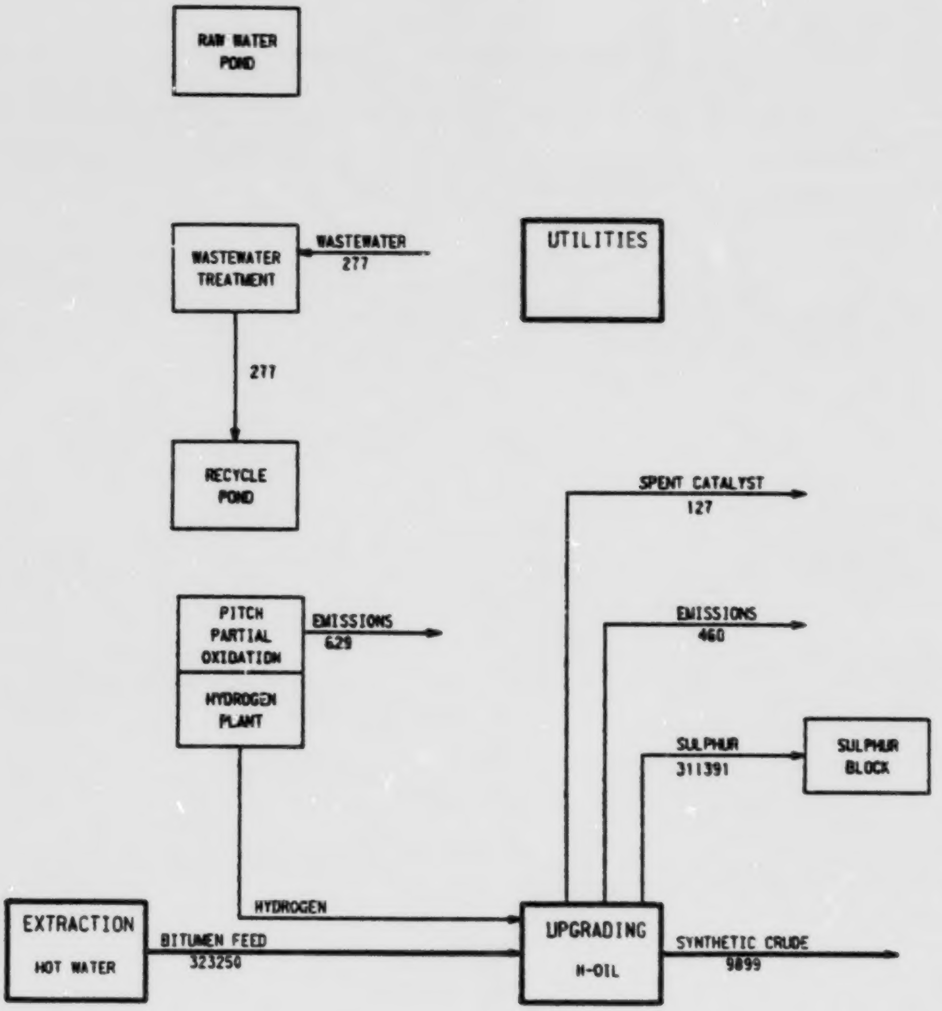
TABLE 5-6

Sulphur Balance - Option 5(1)

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	323 250	100.00
OUTPUT		
Sulphur Block	311 391	96.33
Emissions		
Sulphur Plant	329	0.10
Fired Heaters	116	0.04
Hydrogen Plant	629	0.19
Flare	15	0.00
Liquids		
Wastewater	277	0.09
Other Solids		
Spent Catalyst	127	0.04
Syncrude Product	9 899	3.06
Total Output	322 783	99.86

Note: [1] Option 5 - Hot Water Extraction/Tailings Filtration/H-Oil/Partial Oxidation of Pitch

SULPHUR BALANCE


RAW WATER POND
WASTEWATER TREATMENT
WASTEWATER
277
UTILITIES
277
RECYCLE POND
SPENT CATALYST
127
PITCH PARTIAL OXIDATION
EMISSIONS
629
HYDROGEN PLANT
EMISSIONS
460
SULPHUR
311391
SULPHUR BLOCK
HYDROGEN
EXTRACTION
HOT WATER
BITUMEN FEED
323250
UPGRADING
H-OIL
SYNTHETIC CRUDE
9899

UNITS: TONNES PER YEAR

FIGURE 5-5

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 5 HOT WATER EXTRACTION/TAILINGS
FILTRATION/H-OIL/
PARTIAL OXIDATION OF PITCH

MONENCO CONSULTANTS LIMITED

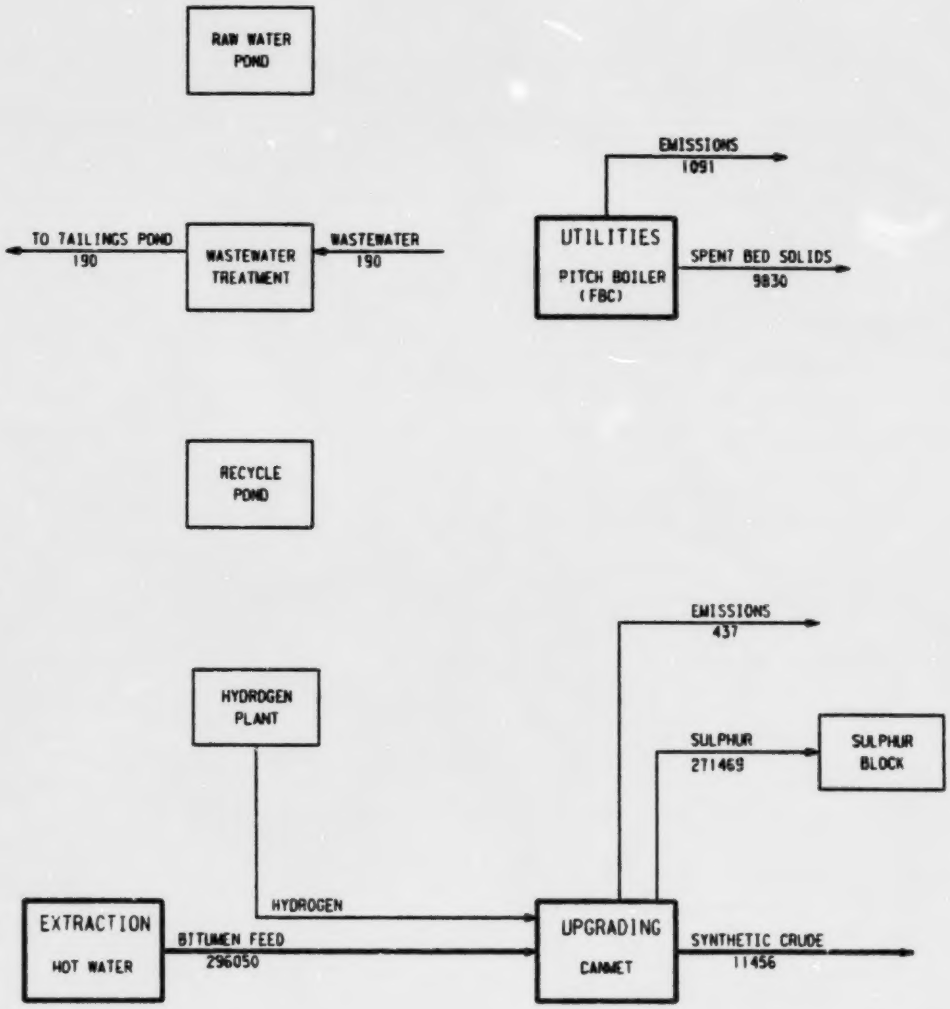
TABLE 5-7

Sulphur Balance - Option 6(1)

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	296 050	100.00
OUTPUT		
Sulphur Block	271 469	91.90
Emissions		
Sulphur Plant	293	0.10
Fired Heaters	129	0.04
Pitch Boilers	1 091	0.37
Flare	15	0.00
Liquids		
Wastewater	190	0.06
Other Solids		
Spent Bed Solids	9 830	3.32
Syncrude Product	11 456	3.87
Total Output	294 473	99.47

Note: [1] Option 6 - Hot Water Extraction/CANMET/Pitch Boilers (FBC)

SULPHUR BALANCE


RAW WATER POND
EMISSIONS
1091
TO TAILINGS POND
190
WASTEWATER TREATMENT
WASTEWATER
190
UTILITIES
PITCH BOILER (FBC)
SPENT BED SOLIDS
9830
RECYCLE POND
EMISSIONS
437
HYDROGEN PLANT
SULPHUR
271469
SULPHUR BLOCK
HYDROGEN
EXTRACTION
HOT WATER
BITUMEN FEED
296050
UPGRADING
CANMET
SYNTHETIC CRUDE
11456

UNITS: TONNES PER YEAR

FIGURE 5-6

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 6 HOT WATER EXTRACTION/CANMET/
PITCH BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

N00214.PFD F24

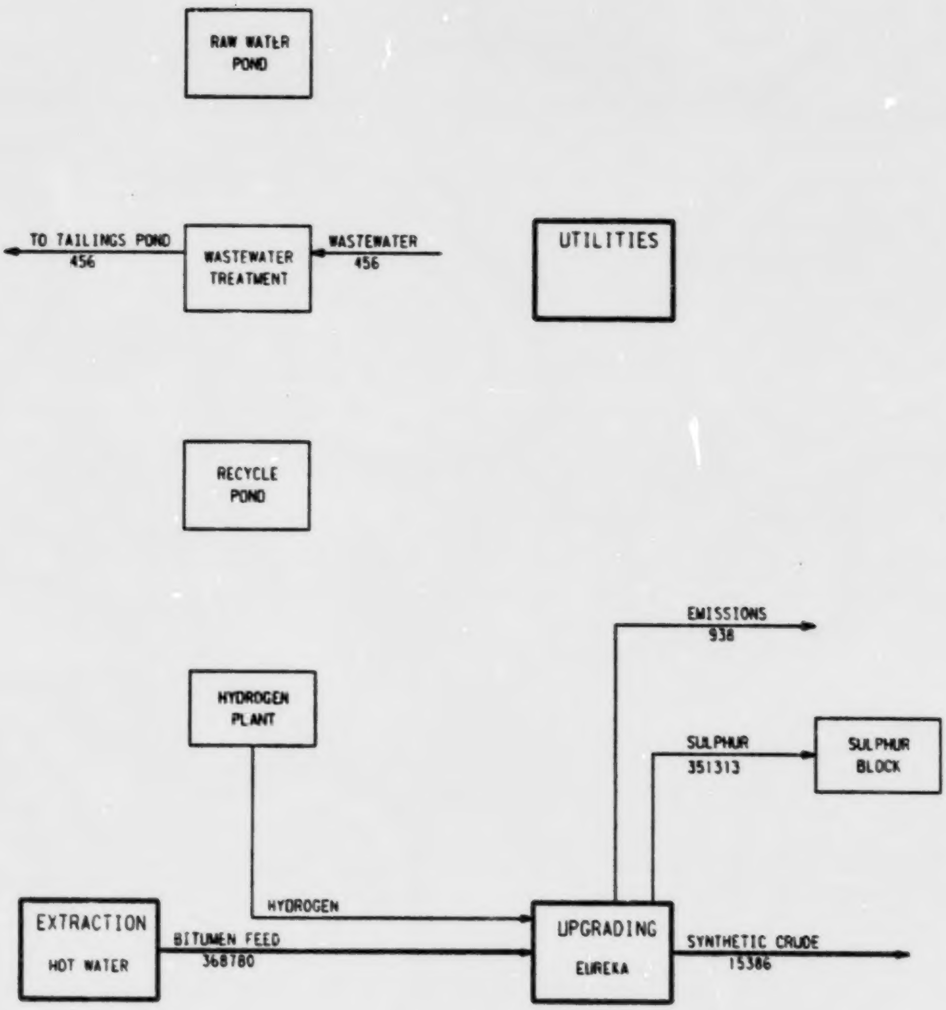
TABLE 5-8

Sulphur Balance - Option 7(1)

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	368 780	100.00
OUTPUT		
Sulphur Block	351 313	96.08
Emissions		
Sulphur Plant	377	0.10
Fired Heaters	150	0.04
Gasification	344	0.09
Flare	67	0.02
Liquids		
Wastewater	456	0.12
Other Solids		
Syncrude Product	15 386	4.17
Total Output	368 093	99.81

Note: [1] Option 7 - Hot Water Extraction/Eureka/Gasification of Pitch

SULPHUR BALANCE


RAW WATER POND
TO TAILINGS POND
456
WASTEWATER TREATMENT
WASTEWATER
456
UTILITIES
RECYCLE POND
EMISSIONS
938
HYDROGEN PLANT
SULPHUR
351313
SULPHUR BLOCK
HYDROGEN
EXTRACTION
HOT WATER
BITUMEN FEED
368780
UPGRADING
EUREKA
SYNTHETIC CRUDE
15386

UNITS: TONNES PER YEAR

FIGURE 5-7

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 7 HOT WATER EXTRACTION/EUREKA/
GASIFICATION OF PITCH

MONENCO CONSULTANTS LIMITED

N08215.PFD F24

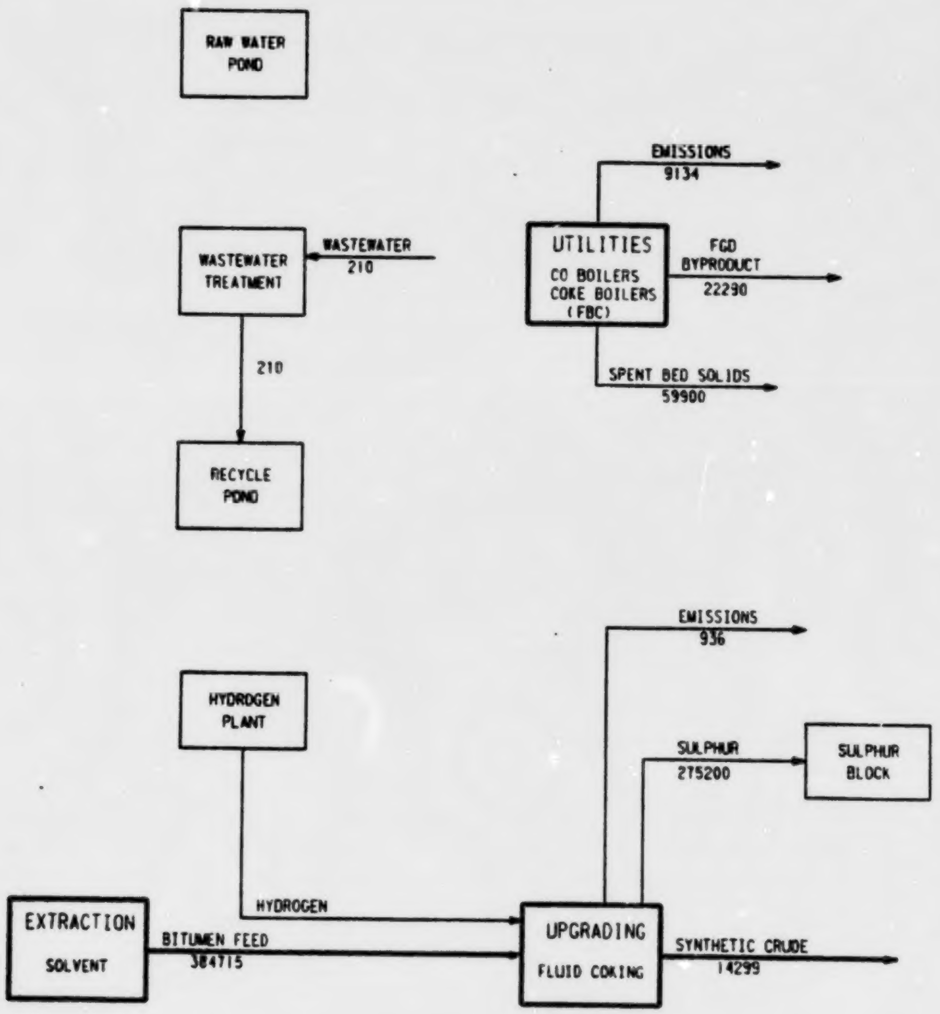
TABLE 5-9

Sulphur Balance - Option 8(1)

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	384 715	100.00
OUTPUT		
Sulphur Block	275 200	71.53
Emissions		
Sulphur Plant	271	0.07
Fired Heaters	655	0.17
CO Boilers	2 442	0.63
Coke Boilers	6 656	1.73
Superheaters	36	0.01
Flare	10	0.00
Liquids		
Wastewater	210	0.05
FGD Byproduct	22 290	5.79
Other Solids		
Spent Bed Material	59 900	15.57
Syncrude Product	14 299	3.72
Total Output	381 969	99.29

Note: [1] Option 8 - Solvent Extraction/Fluid Coking/CO Boilers/Coke Boilers (FBC)

SULPHUR BALANCE


RAW WATER POND
WASTEWATER TREATMENT
WASTEWATER 210
210
RECYCLE POND
UTILITIES
CO BOILERS
COKE BOILERS (FBC)
EMISSIONS 9134
FGD BYPRODUCT 22290
SPENT BED SOLIDS 59900
HYDROGEN PLANT
HYDROGEN
EXTRACTION
SOLVENT
BITUMEN FEED 384715
UPGRADING
FLUID COKING
EMISSIONS 936
SULPHUR 275200
SULPHUR BLOCK
SYNTHETIC CRUDE 14299

UNITS: TONNES PER YEAR

FIGURE 5-8

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 8 SOLVENT EXTRACTION/FLUID COKING/
CO BOILERS/COKE BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

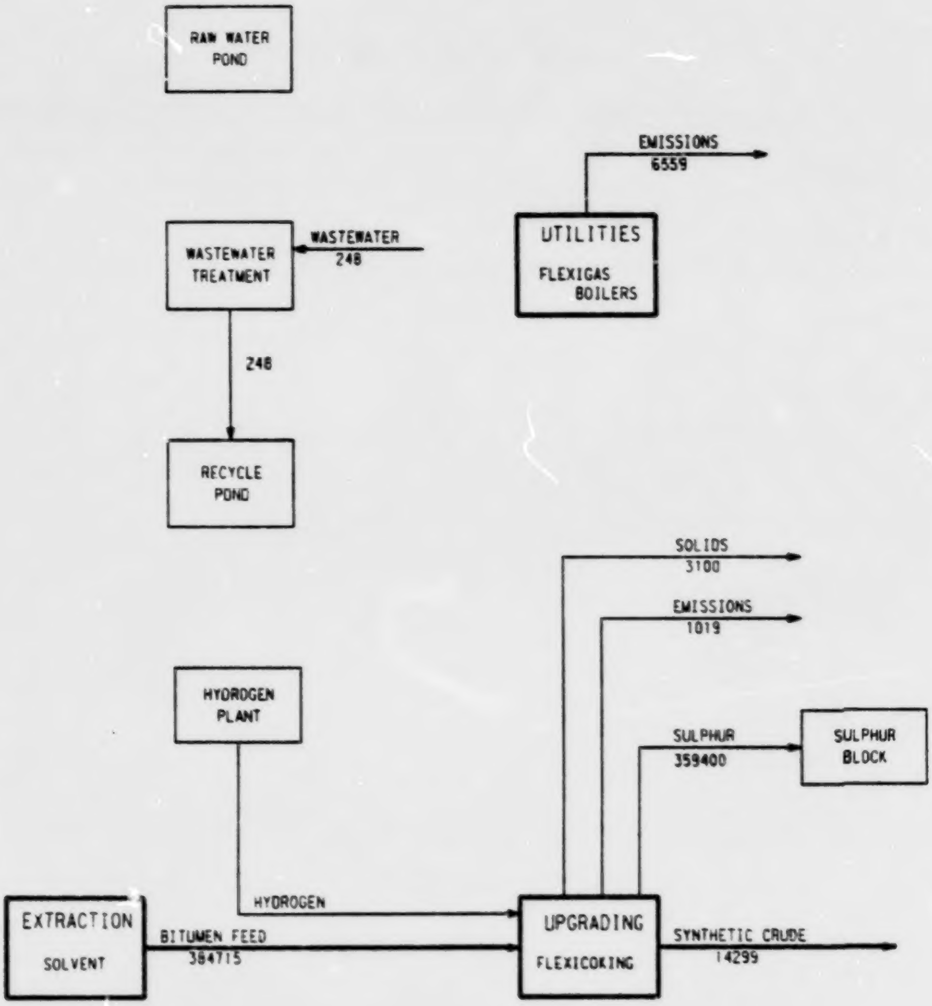
TABLE 5-10

Sulphur Balance - Option 9(1)

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	384 715	100.00
OUTPUT		
Sulphur Block	359 400	93.42
Emissions		
Sulphur Plant	345	0.09
Fired Heaters	664	0.17
Flexigas Boilers	6 559	1.70
Flare	10	0.00
Liquids		
Wastewater	248	0.06
Other Solids		
Char	3 097	0.81
Fines	3	0.00
Syncrude Product	14 299	3.72
Total Output	384 625	99.98

Note: [1] Option 9 - Solvent Extraction/Flexicoking/Flexigas Boilers

SULPHUR BALANCE


RAW WATER POND
EMISSIONS
6559
WASTEWATER TREATMENT
WASTEWATER
248
UTILITIES
FLEXIGAS BOILERS
248
RECYCLE POND
SOLIDS
3100
EMISSIONS
1019
HYDROGEN PLANT
SULPHUR
359400
SULPHUR BLOCK
HYDROGEN
EXTRACTION
SOLVENT
BITUMEN FEED
384715
UPGRADING
FLEXICOKING
SYNTHETIC CRUDE
14299

UNITS: TONNES PER YEAR

FIGURE 5-9

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS FROM A MINING OIL SANDS COMPLEX
OPTION 9 SOLVENT EXTRACTION/FLEXICOKING/ FLEXIGAS BOILERS
MONENCO CONSULTANTS LIMITED

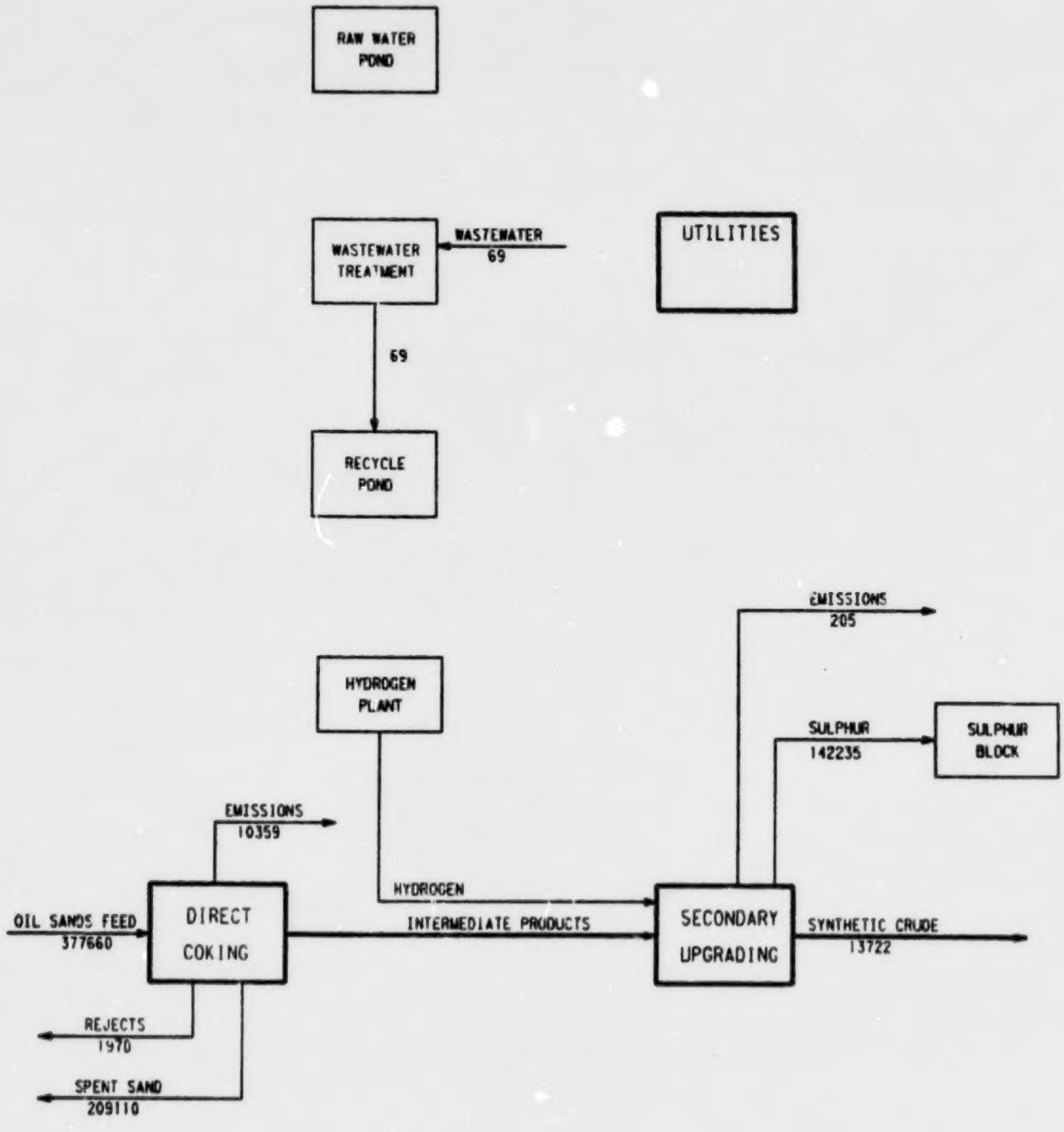
TABLE 5-11

Sulphur Balance - Option 10(1)

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	377 660	100.00
OUTPUT		
Sulphur Block	142 235	37.67
Emissions		
Sulphur Plant	142	0.04
Fired Heaters	53	0.01
Direct Coking	10 359	2.82
Flare	10	0.00
Liquids		
Wastewater	69	0.02
Other Solids		
Rejects	1 970	0.52
Spent Sand	209 110	55.37
Syncrude Product	13 722	3.63
Total Output	377 670	100.00

Note: [1] Option 10 - Direct Coking

SULPHUR BALANCE


RAW WATER POND
WASTEWATER TREATMENT
WASTEWATER
69
69
RECYCLE POND
UTILITIES
HYDROGEN PLANT
EMISSIONS
205
SULPHUR
142235
SULPHUR BLOCK
EMISSIONS
10359
HYDROGEN
OIL SANDS FEED
377660
DIRECT COKING
INTERMEDIATE PRODUCTS
SECONDARY UPGRADING
SYNTHETIC CRUDE
13722
REJECTS
1970
SPENT SAND
209110

UNITS: TONNES PER YEAR

FIGURE 5-10

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS FROM A MINING OIL SANDS COMPLEX
OPTION 10 DIRECT COKING
MONENCO CONSULTANTS LIMITED

TABLE 5-12

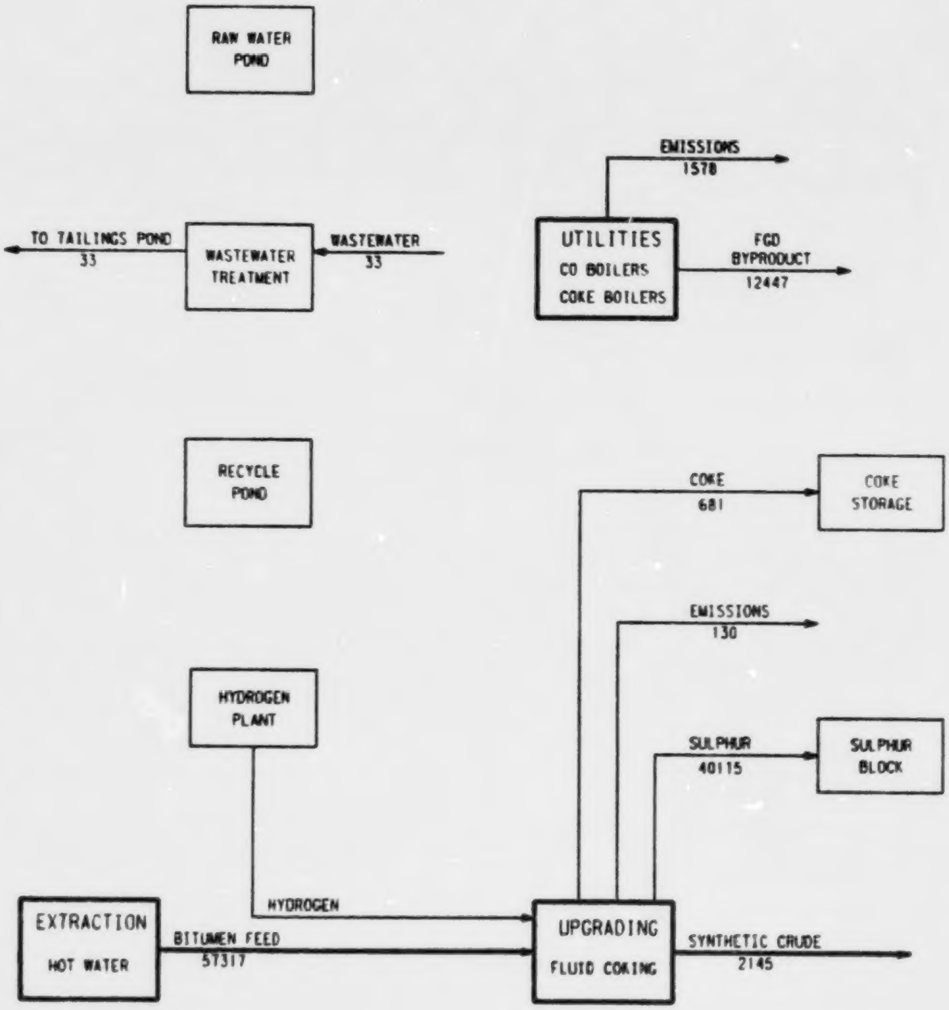
Sulphur Balance - Option 11(1)

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	57 317	100.00
OUTPUT		
Sulphur Block	40 115	70.00
Emissions		
Sulphur Plant	41	0.07
Fired Heaters	84	0.15
CO Boilers	363	0.63
Coke Boilers	1 206	2.11
Superheaters	9	0.02
Flare	5	0.01
Liquids		
Wastewater	33	0.06
FGD Byproduct	12 447	21.72
Other Solids		
Net Coke	681	1.19
Syncrude Product	2 145	3.74
Total Output	57 129	99.67

Note: [1] Option 11 - Hot Water Extraction/Fluid Coking/CO and Coke Boilers

MONENCO CONSULTANTS LIMITED

SULPHUR BALANCE


RAW WATER POND
EMISSIONS
1578
TO TAILINGS POND
33
WASTEWATER TREATMENT
WASTEWATER
33
UTILITIES
CO BOILERS
COKE BOILERS
FGD BYPRODUCT
12447
RECYCLE POND
COKE
681
COKE STORAGE
EMISSIONS
130
HYDROGEN PLANT
SULPHUR
40115
SULPHUR BLOCK
HYDROGEN
EXTRACTION
HOT WATER
BITUMEN FEED
57317
UPGRADING
FLUID COKING
SYNTHETIC CRUDE
2145

UNITS: TONNES PER YEAR

FIGURE 5-11

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION II HOT WATER EXTRACTION/FLUID COKING/
CO & COKE BOILERS
MONENCO CONSULTANTS LIMITED

TABLE 5-13

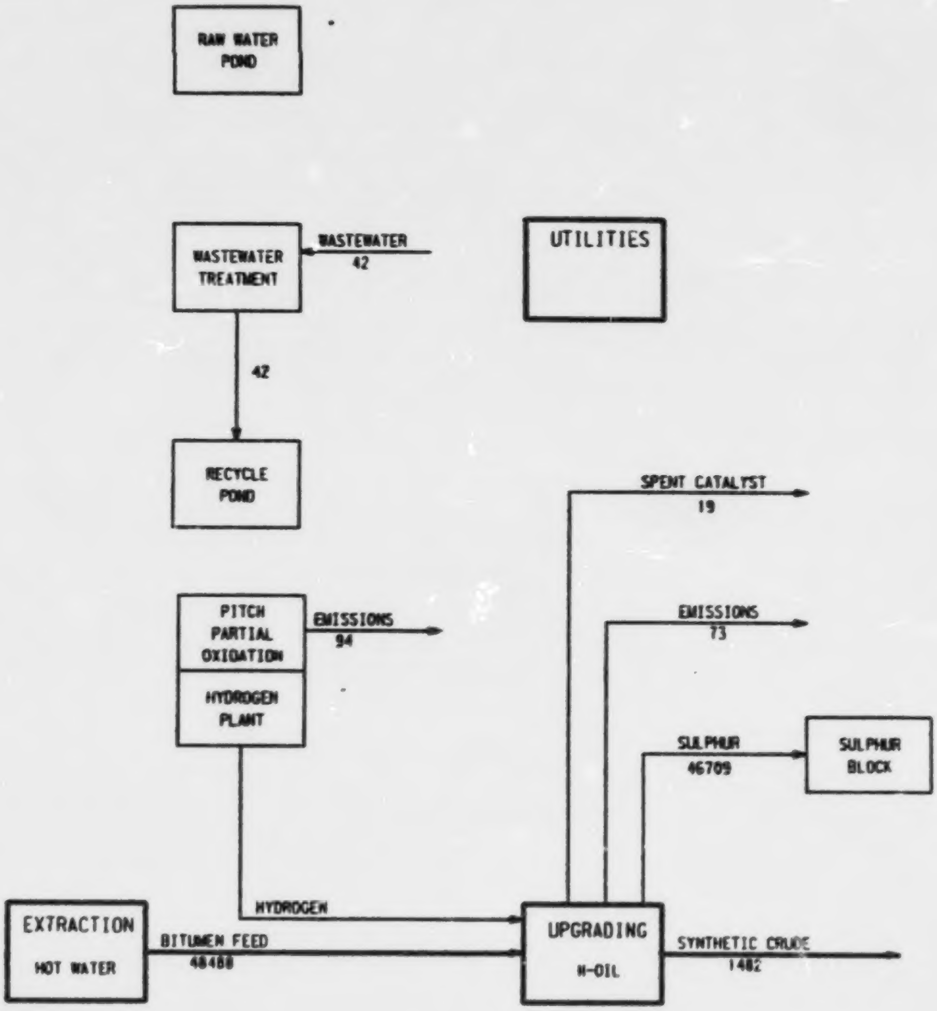
Sulphur Balance - Option 12(1)

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	48 488	100.00
OUTPUT		
Sulphur Block	46 709	96.33
Emissions		
Sulphur Plant	49	0.10
Fired Heaters	17	0.04
Hydrogen Plant	94	0.19
Flare	7	0.01
Liquids		
Wastewater	42	0.09
Other Solids		
Spent Catalyst	19	0.04
Syncrude Product	1 482	3.06
Total Output	48 419	99.86

Note: [1] Option 12 - Hot Water Extraction/Tailings Filtration/H-Oil/Partial Oxidation of Pitch

MONENCO CONSULTANTS LIMITED

SULPHUR BALANCE


RAW WATER POND
WASTEWATER TREATMENT
WASTEWATER
42
UTILITIES
42
RECYCLE POND
SPENT CATALYST
19
PITCH PARTIAL OXIDATION
EMISSIONS
94
HYDROGEN PLANT
EMISSIONS
73
SULPHUR
46709
SULPHUR BLOCK
HYDROGEN
EXTRACTION
HOT WATER
BITUMEN FEED
48488
UPGRADING
H-OIL
SYNTHETIC CRUDE
1482

UNITS: TONNES PER YEAR

FIGURE 5-12

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 12 HOT WATER EXTRACTION/TAILINGS
FILTRATION/H-OIL/
PARTIAL OXIDATION OF PITCH

MONENCO CONSULTANTS LIMITED

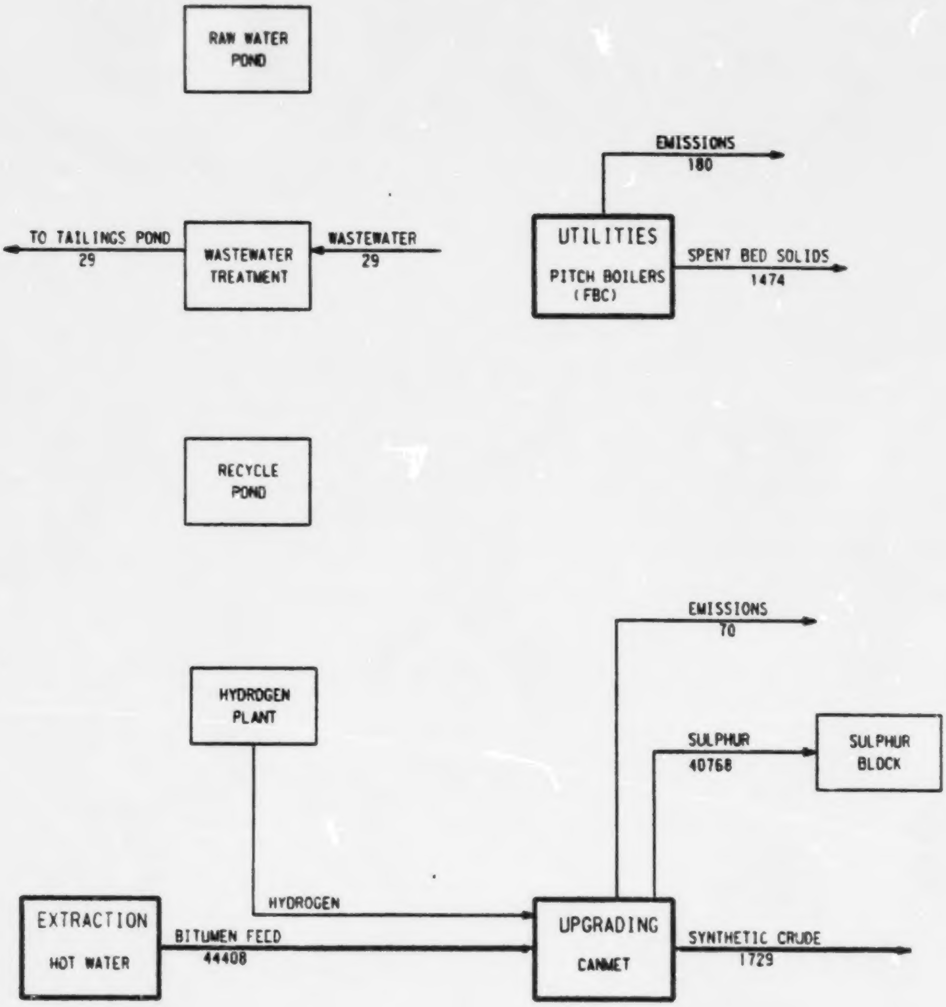
TABLE 5-14

Sulphur Balance - Option 13[1]

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	48 408	100.00
OUTPUT		
Sulphur Block	40 768	91.81
Emissions		
Sulphur Plant	44	0.10
Fired Heaters	19	0.04
Pitch Boilers	180	0.41
Flare	7	0.02
Liquids		
Wastewater	29	0.07
Other Solids		
Spent Bed Solids	1 474	3.32
Syncrude Product	1 729	3.89
Total Output	44 250	99.64

Note: [1] Option 13 - Hot Water Extraction/CANMET/Pitch Boilers (FBC)

SULPHUR BALANCE


RAW WATER POND
EMISSIONS 180
TO TAILINGS POND 29
WASTEWATER TREATMENT
WASTEWATER 29
UTILITIES
PITCH BOILERS (FBC)
SPENT BED SOLIDS 1474
RECYCLE POND
EMISSIONS 70
HYDROGEN PLANT
SULPHUR 40768
SULPHUR BLOCK
HYDROGEN
EXTRACTION
HOT WATER
BITUMEN FEED 44408
UPGRADING
CANMET
SYNTHETIC CRUDE 1729

UNITS: TONNES PER YEAR

FIGURE 5-13

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 13 HOT WATER EXTRACTION/CANMET/
PITCH BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

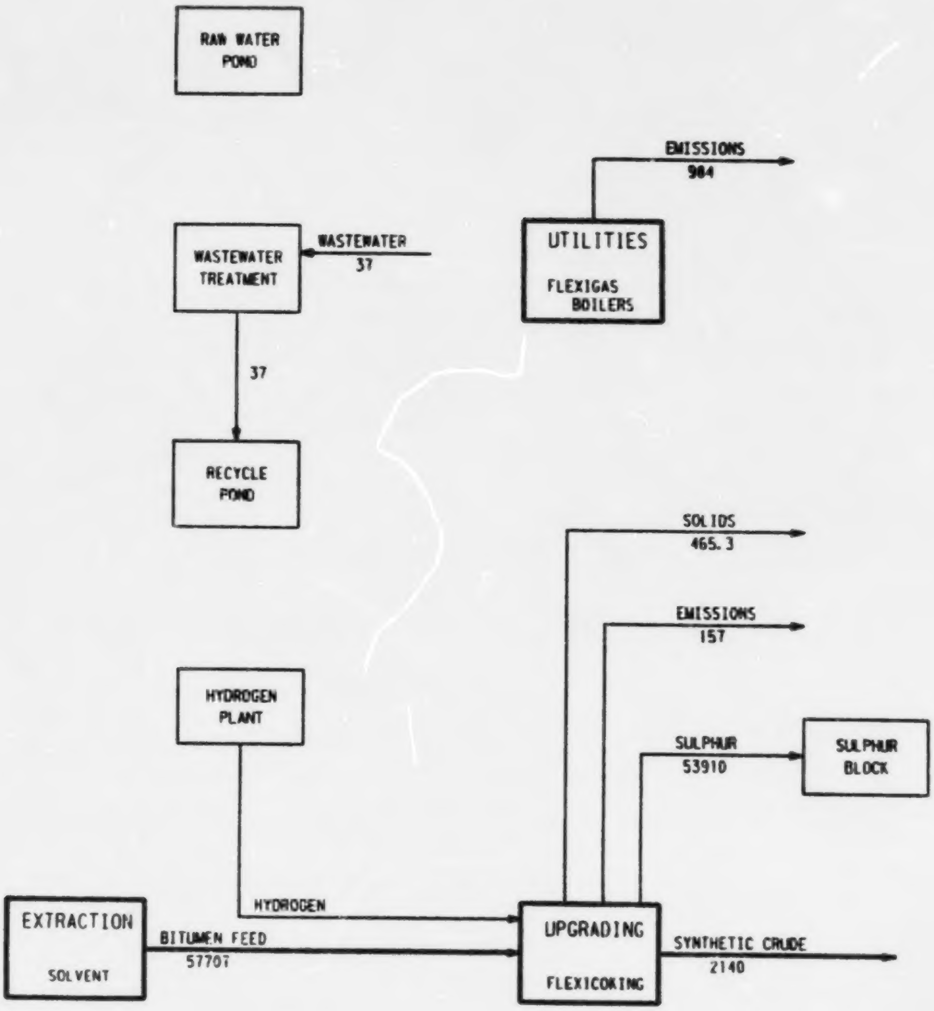
TABLE 5-15

Sulphur Balance - Option 14(1)

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	57 707	100.00
OUTPUT		
Sulphur Block	53 910	93.42
Emissions		
Sulphur Plant	52	0.09
Fired Heaters	100	0.17
Flexigas Boilers	984	1.71
Flare	5	0.01
Liquids		
Wastewater	37	0.06
Other Solids		
Char	465	0.81
Fines	1	0.00
Syncrude Product	2 140	3.71
Total Output	57 693	99.98

Note: [1] Option 14 - Solvent Extraction/Flexicoking/Flexigas Boilers

SULPHUR BALANCE


RAW WATER POND
EMISSIONS
984
WASTEWATER TREATMENT
WASTEWATER
37
UTILITIES
FLEXIGAS BOILERS
37
RECYCLE POND
SOLIDS
465.3
EMISSIONS
157
HYDROGEN PLANT
SULPHUR
53910
SULPHUR BLOCK
EXTRACTION
SOLVENT
HYDROGEN
BITUMEN FEED
57707
UPGRADING
FLEXICOKING
SYNTHETIC CRUDE
2140

UNITS: TONNES PER YEAR

FIGURE 5-14

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS FROM A MINING OIL SANDS COMPLEX

OPTION 14 SOLVENT EXTRACTION/FLEXICOKING/ FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED

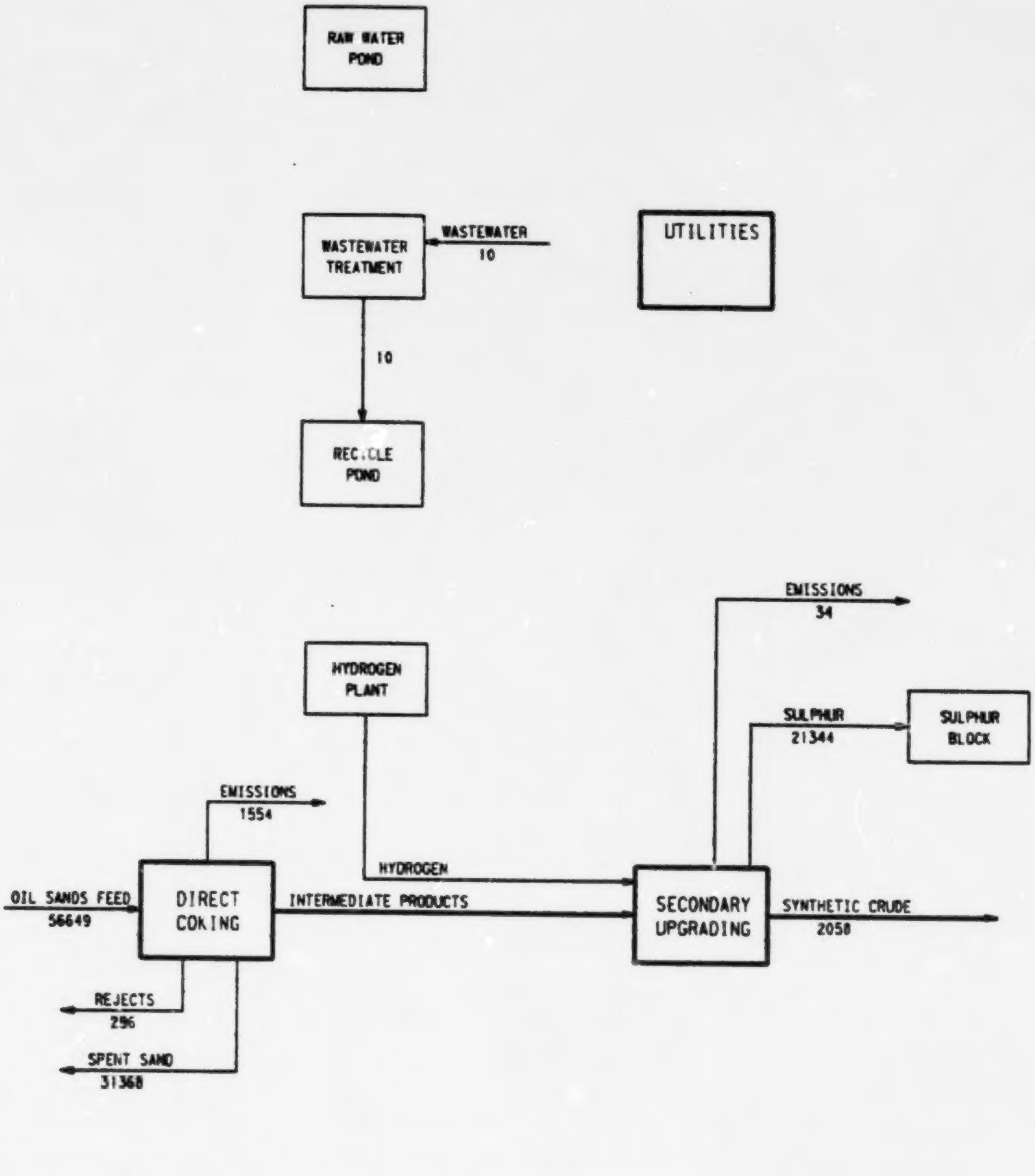
TABLE 5-16

Sulphur Balance - Option 15(1)

Sulphur	tonnes/year	% of input
INPUT		
Bitumen Feed to Upgrading	56 649	100.00
OUTPUT		
Sulphur Block	21 344	37.68
Emissions		
Sulphur Plant	21	0.04
Fired Heaters	8	0.01
Direct Coking	1 554	2.74
Flare	5	0.01
Liquids		
Wastewater	10	0.02
Other Solids		
Rejects	296	0.52
Spent Sand	31 368	55.37
Syncrude Product	2 058	3.63
Total Output	56 664	100.03

Note: [1] Option 15 - Direct Coking

SULPHUR BALANCE


RAW WATER POND
WASTEWATER TREATMENT
WASTEWATER
10
UTILITIES
10
RECYCLE POND
EMISSIONS
34
HYDROGEN PLANT
SULPHUR
21344
SULPHUR BLOCK
EMISSIONS
1554
HYDROGEN
OIL SANDS FEED
56649
DIRECT COKING
INTERMEDIATE PRODUCTS
SECONDARY UPGRADING
SYNTHETIC CRUDE
2058
REJECTS
296
SPENT SAND
31368

UNITS: TONNES PER YEAR

FIGURE 5-15

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 15 DIRECT COKING

MONENCO CONSULTANTS LIMITED

TABLE 5-17

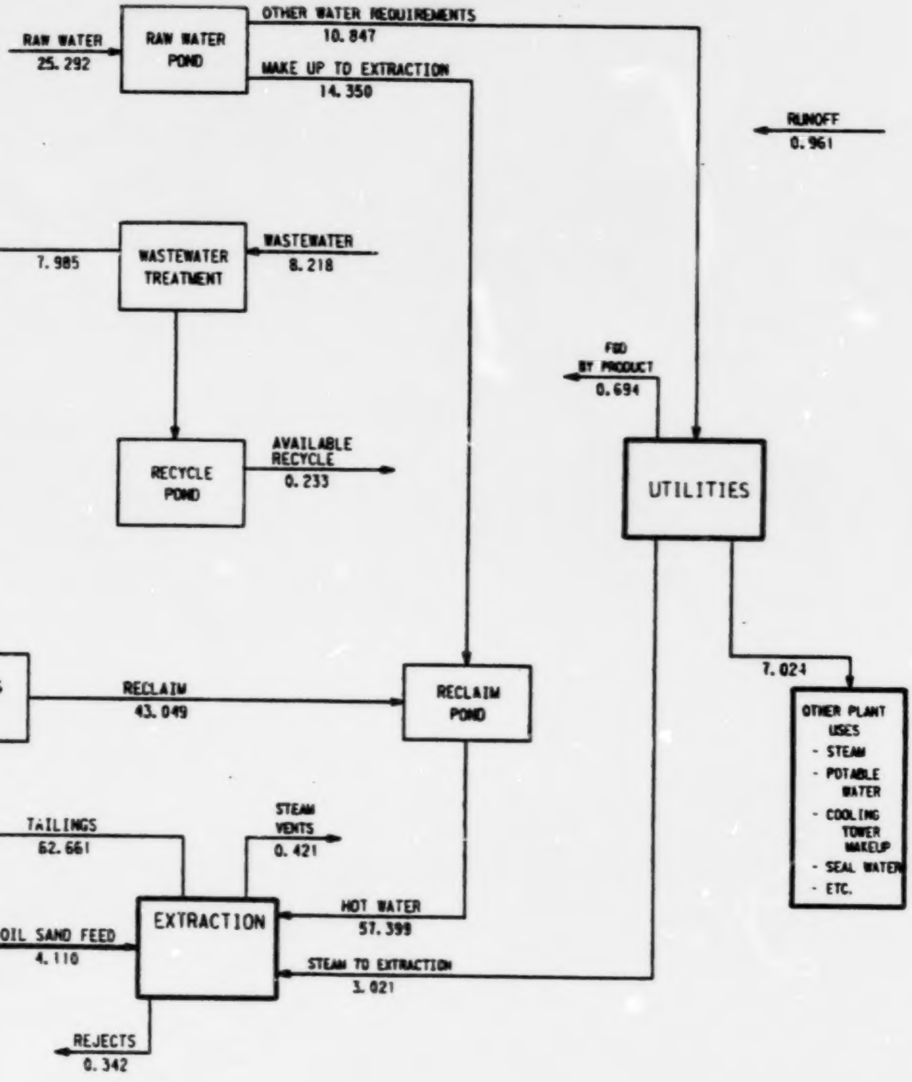
Water Balance - Option 1(1)

Water	Input m^3x10^6	Output m^3x10^6
Raw Oil Sands Feed	4.110	
Rejects		0.342
Steam to Extraction	3.021	
Reclaim from Tailings Pond	43.049	
Make-up to Extraction	14.350	
Tailings		62.661
Runoff	0.961	
Wastewater		8.218
Vents		0.421
Available Recycle	0.233	
Other Raw Water Input	7.024	
Net Make-up to FGD	0.784	
FGD Byproduct		0.694
Total	73.532	72.336

Notes: [1] Option 1 - Hot Water Extraction/Fluid Coking/CO and Coke Boilers

MONENCO CONSULTANTS LIMITED

WATER MANAGEMENT SCHEME


RAW WATER
25.292
RAW WATER POND
OTHER WATER REQUIREMENTS
10.847
MAKE UP TO EXTRACTION
14.350
RUNOFF
0.961
WASTEWATER TREATMENT
WASTEWATER
8.218
7.985
FGD BY PRODUCT
0.694
RECYCLE POND
AVAILABLE RECYCLE
0.233
UTILITIES
TAILINGS POND
RECLAIM
43.049
RECLAIM POND
7.024
OTHER PLANT USES
- STEAM
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
TAILINGS
62.661
STEAM VENTS
0.421
MINING
OIL SAND FEED
4.110
EXTRACTION
HOT WATER
57.399
STEAM TO EXTRACTION
3.021
REJECTS
0.342

UNITS: 10^6 CUBIC METRES PER YEAR

FIGURE 5-16

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX
OPTION 1 HOT WATER EXTRACTION/FLUID COKING/
CO & COKE BOILERS
MONENCO CONSULTANTS LIMITED

N00133.PFD F24

TABLE 5-18

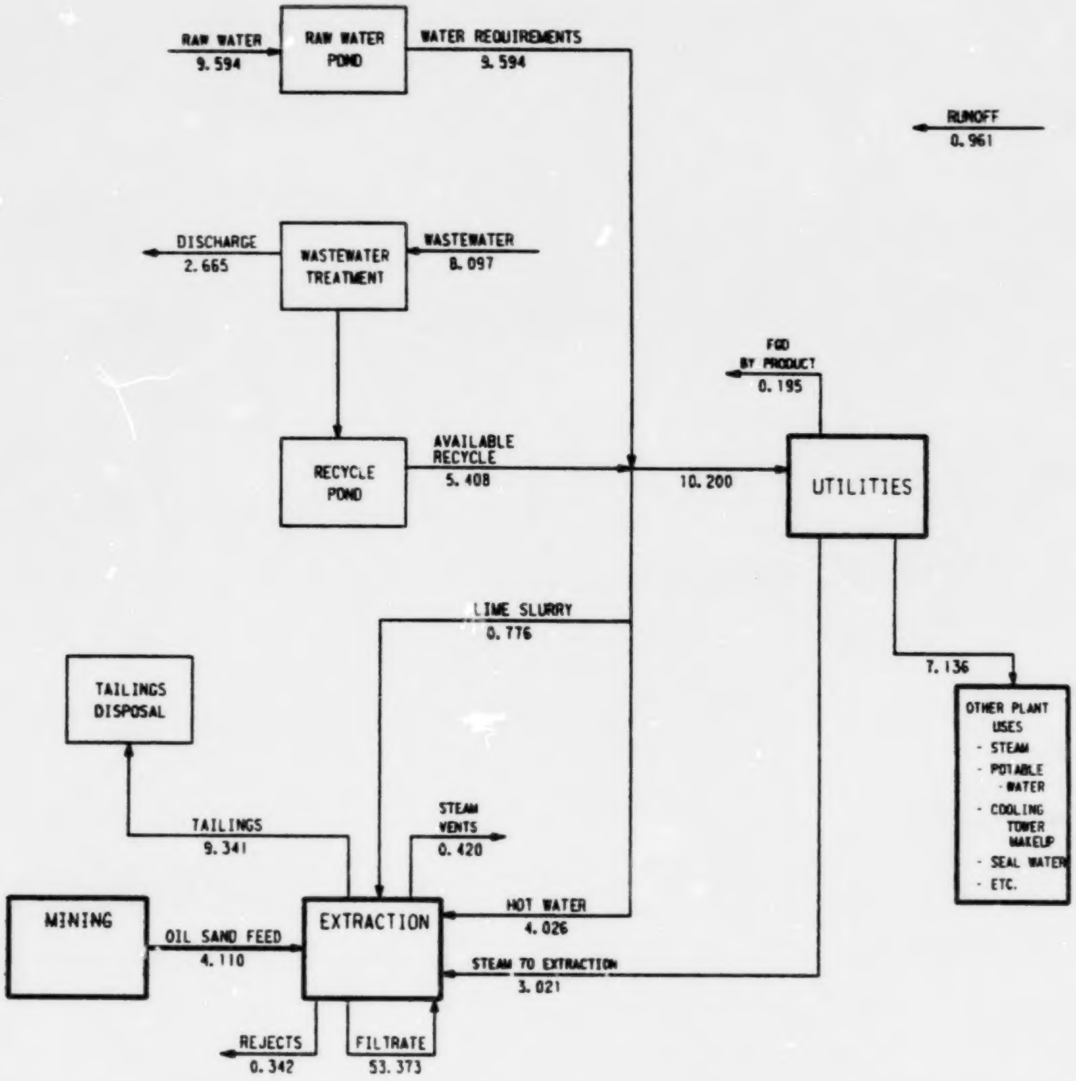
Water Balance - Option 2(1)

Water	Input $m^3 x10^6$	Output $m^3 x10^6$
Raw Oil Sands Feed	4.110	
Rejects		0.342
Extraction Make-up	4.026	
Steam to Extraction	3.021	
Lime Slurrying - Tailings Filtration	0.776	
Tailings		9.341
Filtrate	53.373	53.373
Precipitation Runoff	0.961	
Available Recycle Water	5.408	
Other Raw Water Input	1.728	
Wastewater		8.097
Vents		0.420
Net Make-up to FGD	0.043	
FGD Byproduct		0.195
Total	73.446	71.768

Notes: [1] Option 2 - Hot Water Extraction/Tailings Filtration/Fluid Coking/Gasification of Coke

MONENCO CONSULTANTS LIMITED

WATER MANAGEMENT SCHEME


RAW WATER
9.594
RAW WATER POND
WATER REQUIREMENTS
9.594
RUNOFF
0.961
DISCHARGE
2.665
WASTEWATER TREATMENT
WASTEWATER
8.097
FGD BY PRODUCT
0.195
RECYCLE POND
AVAILABLE RECYCLE
5.408
10.200
UTILITIES
LIME SLURRY
0.776
7.136
TAILINGS DISPOSAL
OTHER PLANT USES
- STEAM
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
TAILINGS
9.341
STEAM VENTS
0.420
MINING
EXTRACTION
HOT WATER
4.026
OIL SAND FEED
4.110
STEAM TO EXTRACTION
3.021
REJECTS
0.342
FILTRATE
53.373

UNITS: 10^6 CUBIC METRES PER YEAR

FIGURE 5-17

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS FROM A MINING OIL SANDS COMPLEX

OPTION 2 HOT WATER EXTRACTION/TAILINGS FILTRATION/FLUID COKING/ GASIFICATION OF COKE

MONENCO CONSULTANTS LIMITED

M00134.PFD F24

TABLE 5-19

Water Balance - Option 3(1)

Water	Input $m^3 x 10^6$	Output $m^3 x 10^6$
Raw Oil Sands Feed	4.110	
Rejects		0.342
Steam to Extraction	3.021	
Reclaim from Tailings Pond	43.049	
Make-up to Extraction	14.350	
Tailings		62.661
Runoff	0.961	
Wastewater		8.172
Vents		0.420
Available Recycle	0.248	
Other Raw Water Input	6.963	
Total	72.702	71.595

Notes: [1] Option 3 - Hot Water Extraction/Flexicoking/Flexigas Boilers

WATER MANAGEMENT SCHEME

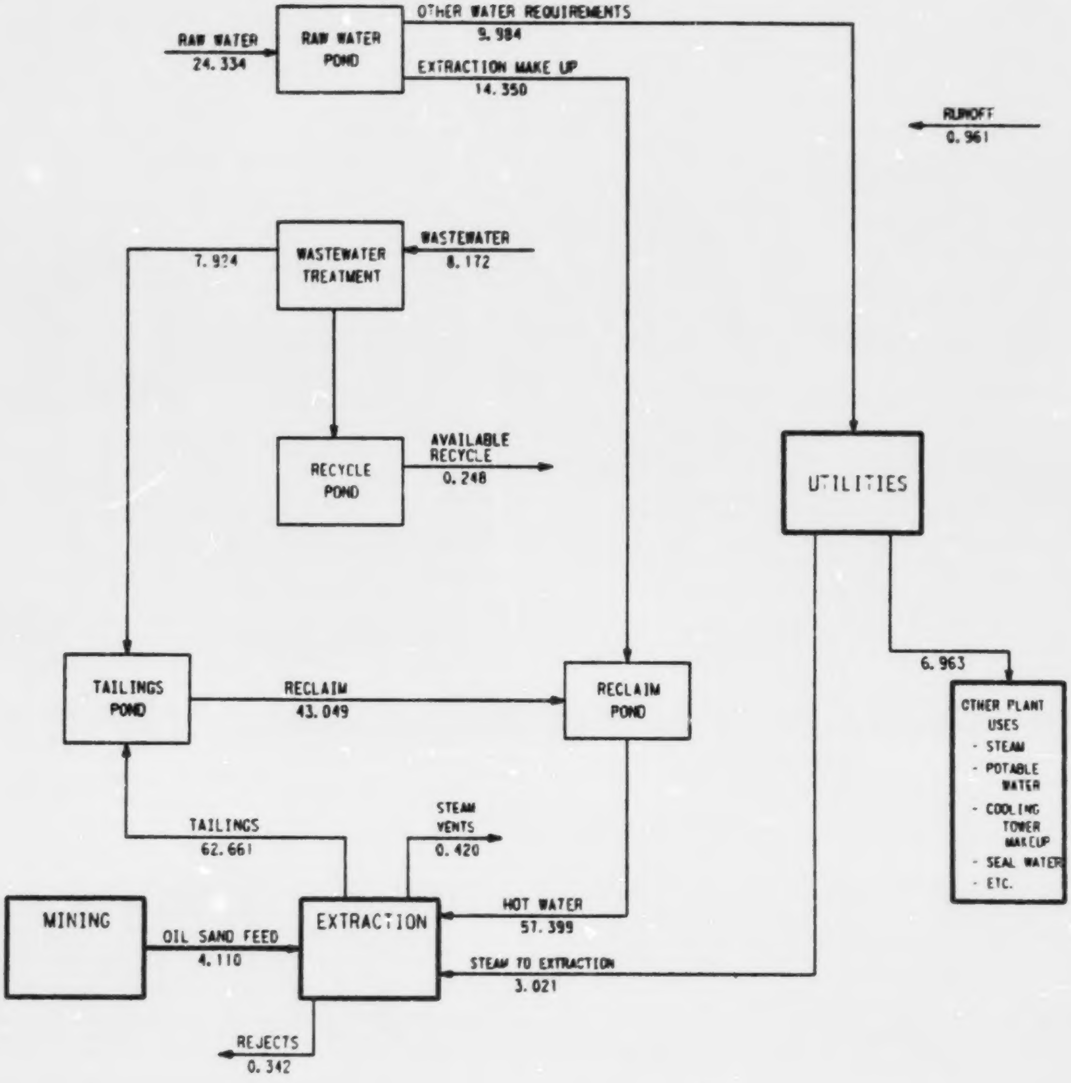

RAW WATER
24.334
RAW WATER POND
OTHER WATER REQUIREMENTS
9.984
EXTRACTION MAKE UP
14.350
RUNOFF
0.961
WASTEWATER TREATMENT
WASTEWATER
8.172
7.924
RECYCLE POND
AVAILABLE RECYCLE
0.248
UTILITIES
6.963
OTHER PLANT USES
- STEAM
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
TAILINGS POND
RECLAIM
43.049
RECLAIM POND
TAILINGS
62.661
STEAM VENTS
0.420
HOT WATER
57.399
MINING
OIL SAND FEED
4.110
EXTRACTION
STEAM TO EXTRACTION
3.021
REJECTS
0.342

FIGURE 5-16

UNITS: 10^6 CUBIC METRES PER YEAR

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 3 HOT WATER EXTRACTION/FLEXICOKING/
FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED

TABLE 5-20

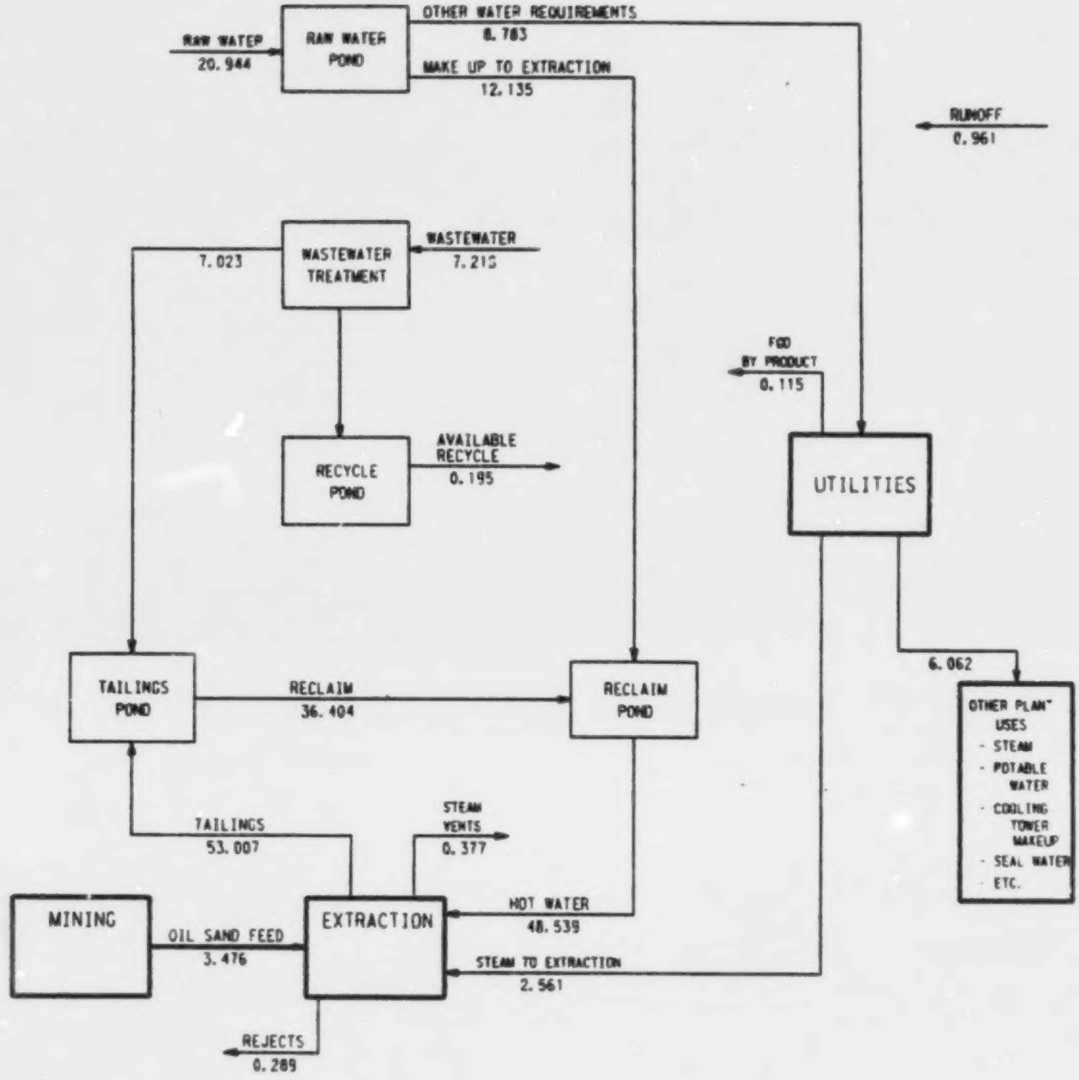
Water Balance - Option 4(1)

Water	Input $m^3 x 10^6$	Output $m^3 x 10^6$
Raw Oil Sands Feed	3.476	
Rejects		0.289
Steam to Extraction	2.561	
Reclaim from Tailings Pond	36.404	
Make-up to Extraction	12.135	
Tailings		53.007
Runoff	0.961	
Wastewater		7.218
Vents		0.377
Available Recycle	0.195	
Other Raw Water Input	6.062	
Net Make-up to FGD	0.160	
FGD Byproduct		0.115
Total	61.954	61.006

Notes: [1] Option 4 - Hot Water Extraction/H-Oil/Pitch Boilers

MONENCO CONSULTANTS LIMITED

WATER MANAGEMENT SCHEME


RAW WATER
20.944
RAW WATER POND
OTHER WATER REQUIREMENTS
8.783
MAKE UP TO EXTRACTION
12.135
RUNOFF
0.961
WASTEWATER TREATMENT
WASTEWATER
7.218
7.023
FGD BY PRODUCT
0.115
RECYCLE POND
AVAILABLE RECYCLE
0.195
UTILITIES
6.062
OTHER PLANT USES
- STEAM
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
TAILINGS POND
RECLAIM
36.404
RECLAIM POND
TAILINGS
53.007
STEAM VENTS
0.377
MINING
OIL SAND FEED
3.476
EXTRACTION
HOT WATER
48.539
STEAM TO EXTRACTION
2.561
REJECTS
0.289

UNITS: 10^6 CUBIC METRES PER YEAR

FIGURE 5-19

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS FROM A MINING OIL SANDS COMPLEX
OPTION 4 HOT WATER EXTRACTION/ H-OIL/PITCH BOILERS
MONENCO CONSULTANTS LIMITED

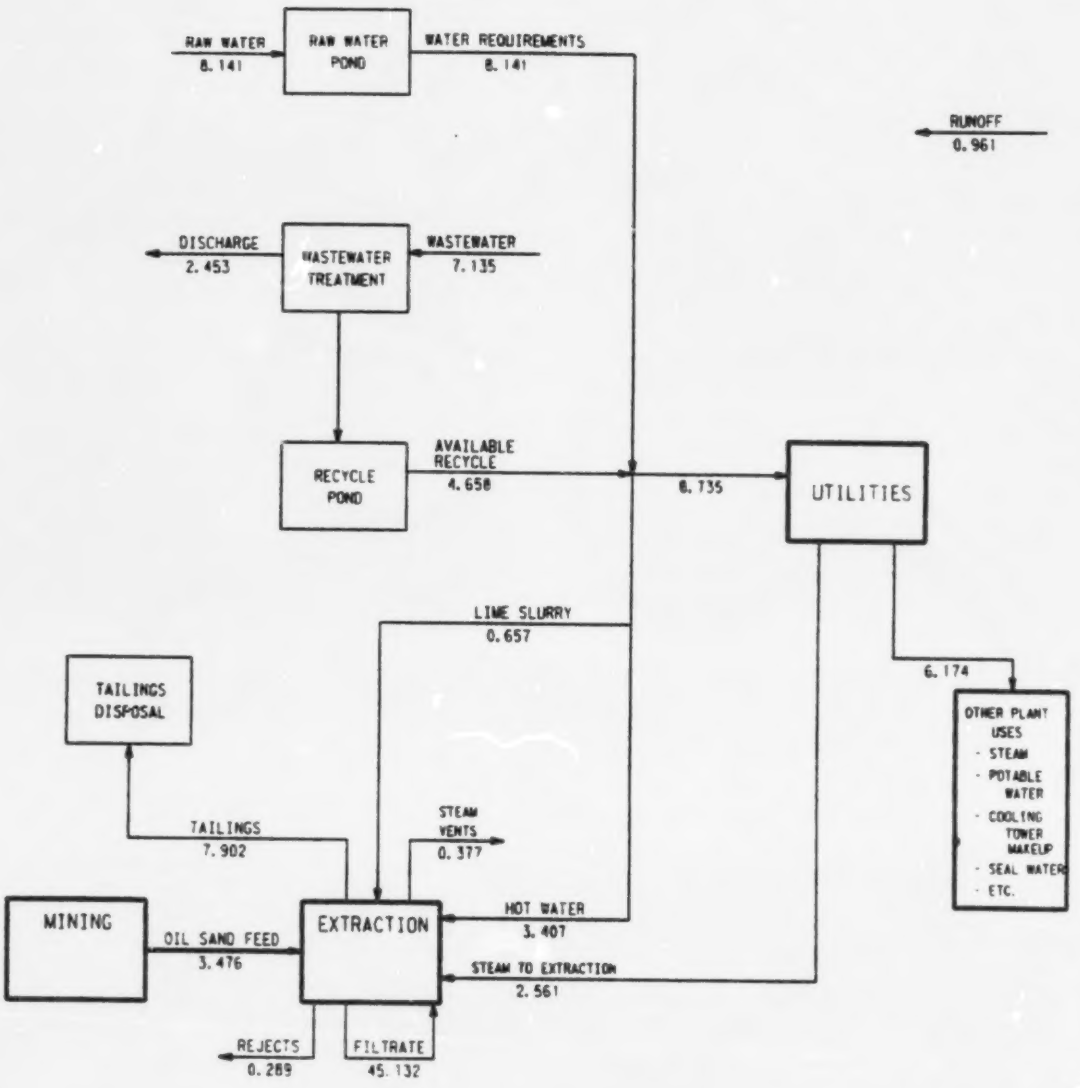
TABLE 5-21

Water Balance - Option 5(1)

Water	Input m^3x10^6	Output m^3x10^6
Raw Oil Sands Feed	3.476	
Rejects		0.289
Extraction Make-up	3.407	
Steam to Extraction	2.561	
Lime Slurrying - Tailings Filtration	0.657	
Tailings		7.902
Filtrate	45.132	45.132
Precipitation Runoff	0.961	
Available Recycle Water	3.689	
Other Raw Water Input	1.516	
Wastewater		7.135
Vents		0.377
Total	61.399	60.835

Notes: [1] Option 5 - Hot Water Extraction/Tailings Filtration/H-Oil/ Partial Oxidation of Pitch

WATER MANAGEMENT SCHEME


RAW WATER
8.141
RAW WATER POND
WATER REQUIREMENTS
8.141
RUNOFF
0.961
DISCHARGE
2.453
WASTEWATER TREATMENT
WASTEWATER
7.135
RECYCLE POND
AVAILABLE RECYCLE
4.658
8.735
UTILITIES
LIME SLURRY
0.657
6.174
OTHER PLANT USES
- STEAM
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
TAILINGS DISPOSAL
TAILINGS
7.902
STEAM VENTS
0.377
MINING
EXTRACTION
HOT WATER
3.407
OIL SAND FEED
3.476
STEAM TO EXTRACTION
2.561
REJECTS
0.289
FILTRATE
45.132

UNITS: 10^6 CUBIC METRES PER YEAR

FIGURE 5-20

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 5 HOT WATER EXTRACTION/TAILINGS
FILTRATION/H-OIL/
PARTIAL OXIDATION OF PITCH

MONENCO CONSULTANTS LIMITED

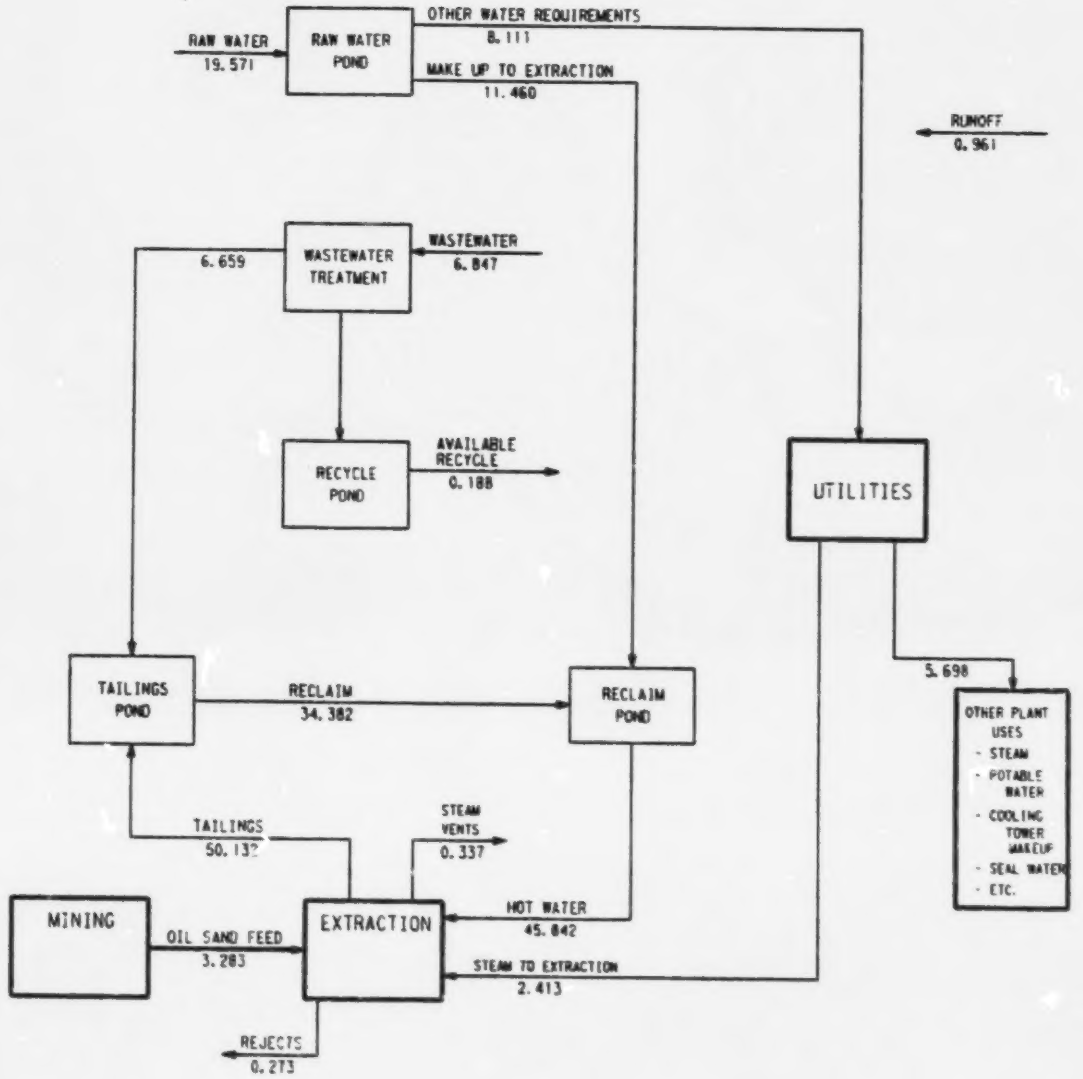
TABLE 5-22

Water Balance - Option 6(1)

Water	Input m^3x10^6	Output m^3x10^6
Raw Oil Sands Feed	3.283	
Rejects		0.273
Steam to Extraction	2.413	
Reclaim from Tailings Pond	34.382	
Make-up to Extraction	11.460	
Tailings		50.132
Runoff	0.961	
Wastewater		6.847
Vents		0.377
Available Recycle	0.188	
Other Raw Water Input	5.698	
Total	58.385	57.589

Notes: [1] Option 6 - Hot Water Extraction/CANMET/Pitch Boilers (FBC)

WATER MANAGEMENT SCHEME


RAW WATER
19.571
RAW WATER POND
OTHER WATER REQUIREMENTS
8.111
MAKE UP TO EXTRACTION
11.460
RUNOFF
0.961
WASTEWATER TREATMENT
WASTEWATER
6.847
6.659
RECYCLE POND
AVAILABLE RECYCLE
0.188
UTILITIES
5.698
OTHER PLANT USES
- STEAM
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
TAILINGS POND
RECLAIM
34.382
RECLAIM POND
TAILINGS
50.132
STEAM VENTS
0.337
MINING
OIL SAND FEED
3.283
EXTRACTION
HOT WATER
45.842
STEAM TO EXTRACTION
2.413
REJECTS
0.273

UNITS: 10^6 CUBIC METRES PER YEAR

FIGURE 5-21

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS FROM A MINING OIL SANDS COMPLEX
OPTION 6 HOT WATER EXTRACTION/CANMET/ PITCH BOILERS (FBC)
MONENCO CONSULTANTS LIMITED

TABLE 5-23

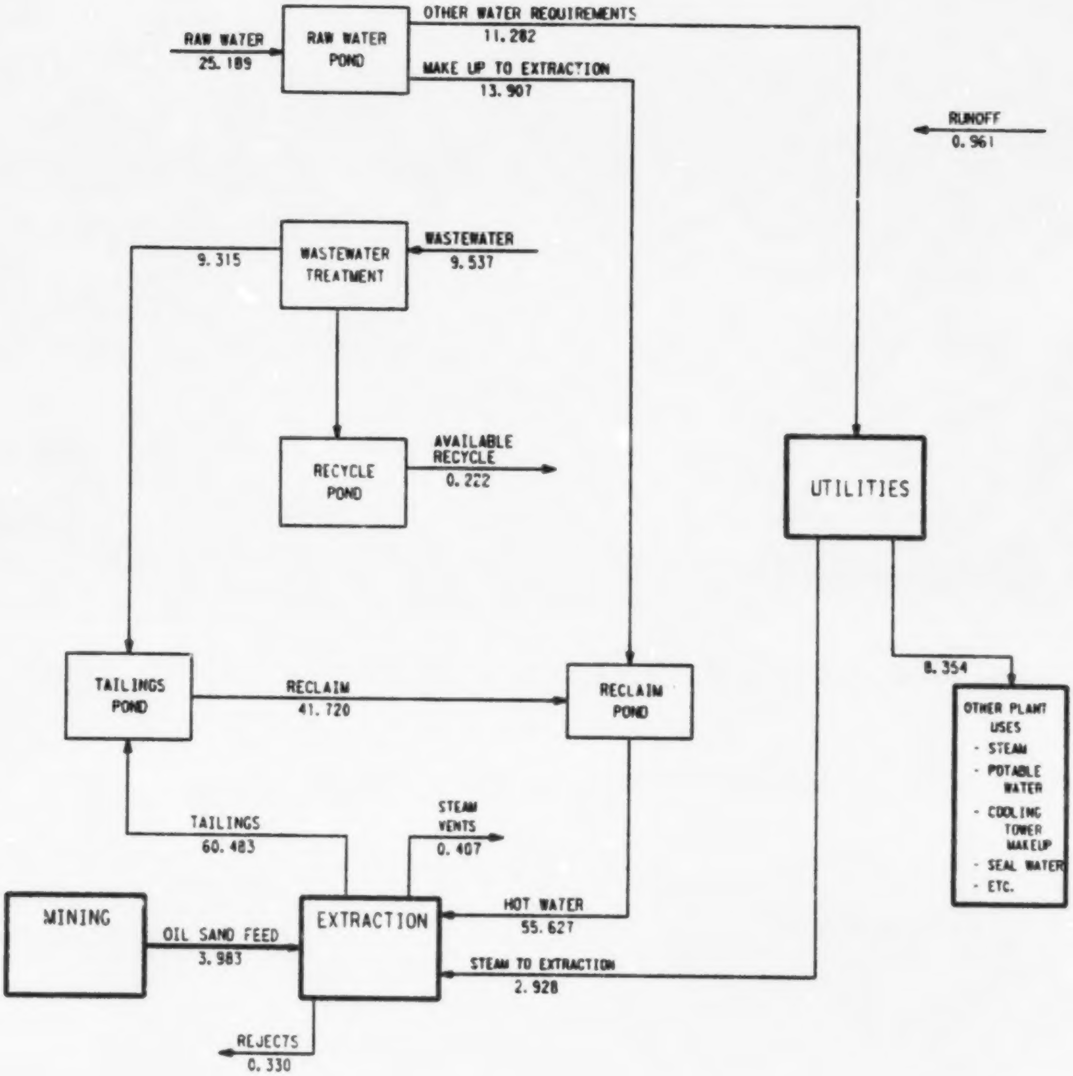
Water Balance - Option 7(1)

Water	Input $m^3 x 10^6$	Output $m^3 x 10^6$
Raw Oil Sands Feed	3.983	
Rejects		0.330
Steam to Extraction	2.928	
Reclaim from Tailings Pond	41.720	
Make-up to Extraction	13.907	
Tailings		60.483
Runoff	0.961	
Wastewater		9.537
Vents		0.407
Available Recycle	0.222	
Other Raw Water Input	8.354	
Total	72.075	70.757

Notes: [1] Option 7 - Hot Water Extraction/Eureka/Gasification of Pitch

MONENCO CONSULTANTS LIMITED

WATER MANAGEMENT SCHEME


RAW WATER
25.189
RAW WATER POND
OTHER WATER REQUIREMENTS
11.282
MAKE UP TO EXTRACTION
13.907
RUNOFF
0.961
WASTEWATER
9.537
WASTEWATER TREATMENT
9.315
RECYCLE POND
AVAILABLE RECYCLE
0.222
UTILITIES
8.354
OTHER PLANT USES
- STEAM
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
TAILINGS POND
RECLAIM
41.720
RECLAIM POND
TAILINGS
60.483
STEAM VENTS
0.407
MINING
OIL SAND FEED
3.983
EXTRACTION
HOT WATER
55.627
STEAM TO EXTRACTION
2.928
REJECTS
0.330

UNITS: 10^6 CUBIC METRES PER YEAR

FIGURE 5-22

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 7 HOT WATER EXTRACTION/EUREKA/
GASIFICATION OF PITCH

MONENCO CONSULTANTS LIMITED

N00139.PFD F24

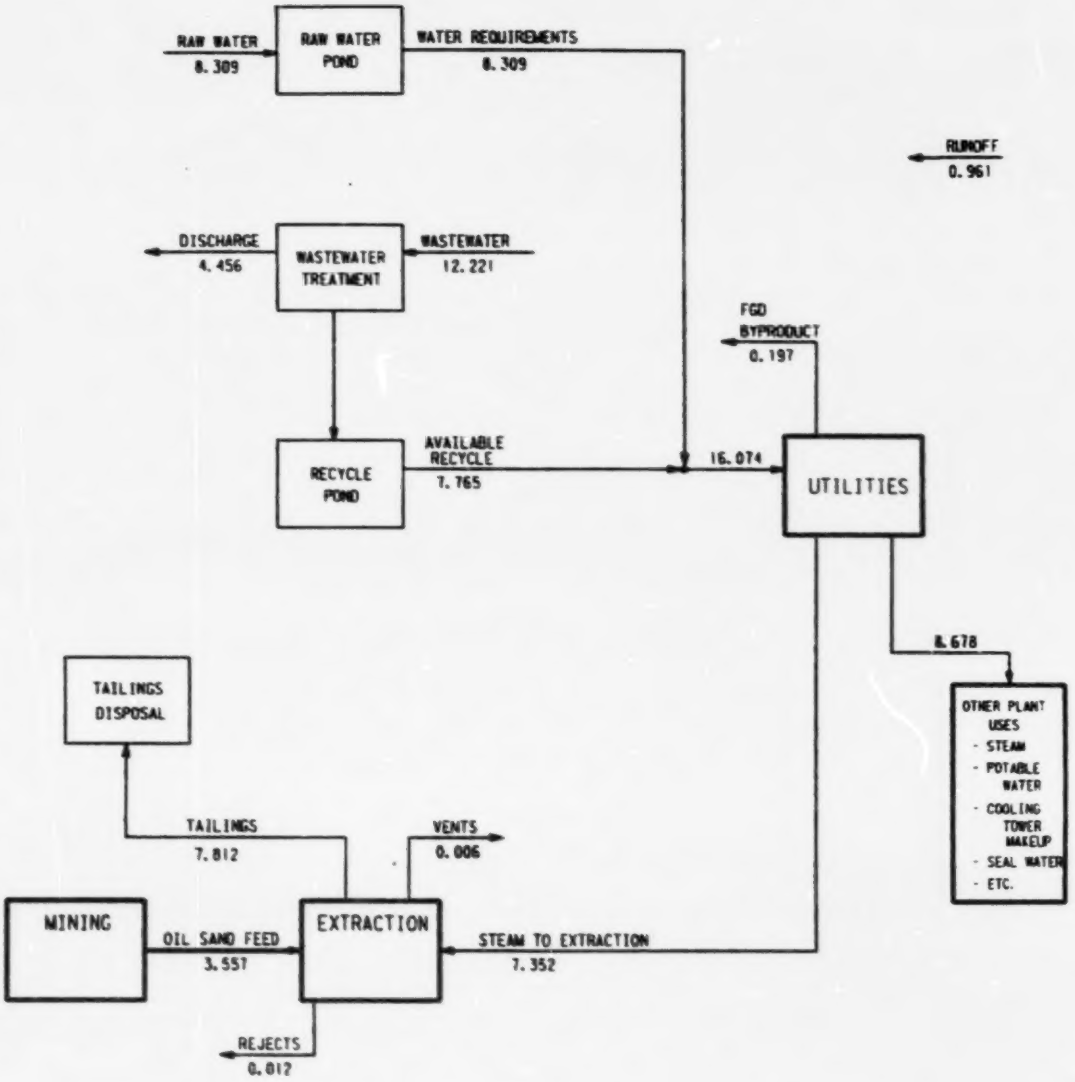
TABLE 5-24

Water Balance - Option 8(1)

Water	Input m^3x10^6	Output m^3x10^6
Raw Oil Sands Feed	3.557	
Rejects		0.012
Tailings		7.812
Steam to Extraction	7.352	
Extraction Wastewater		3.082
Extraction Vents		0.006
Runoff	0.961	
Wastewater		9.139
Available Recycle	7.765	
Other Raw Water Input	0.913	
FGD Byproduct	0.044	
Make-up to FGD		0.197
Total	20.592	20.248

Notes: [1] Option 8 - Solvent Extraction/Fluid Coking/CO Boilers/Coke Boilers (FBC)

WATER MANAGEMENT SCHEME


RAW WATER
8.309
RAW WATER POND
WATER REQUIREMENTS
8.309
RUNOFF
0.961
DISCHARGE
4.456
WASTEWATER TREATMENT
WASTEWATER
12.221
FGD BYPRODUCT
0.197
RECYCLE POND
AVAILABLE RECYCLE
7.765
16.074
UTILITIES
8.678
OTHER PLANT USES
- STEAM
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
TAILINGS DISPOSAL
TAILINGS
7.812
VENTS
0.006
MINING
OIL SAND FEED
3.557
EXTRACTION
STEAM TO EXTRACTION
7.352
REJECTS
0.012

UNITS: 10^6 CUBIC METRES PER YEAR

FIGURE 5-23

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 8 SOLVENT EXTRACTION/FLUID COKING/
CO BOILERS/COKE BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

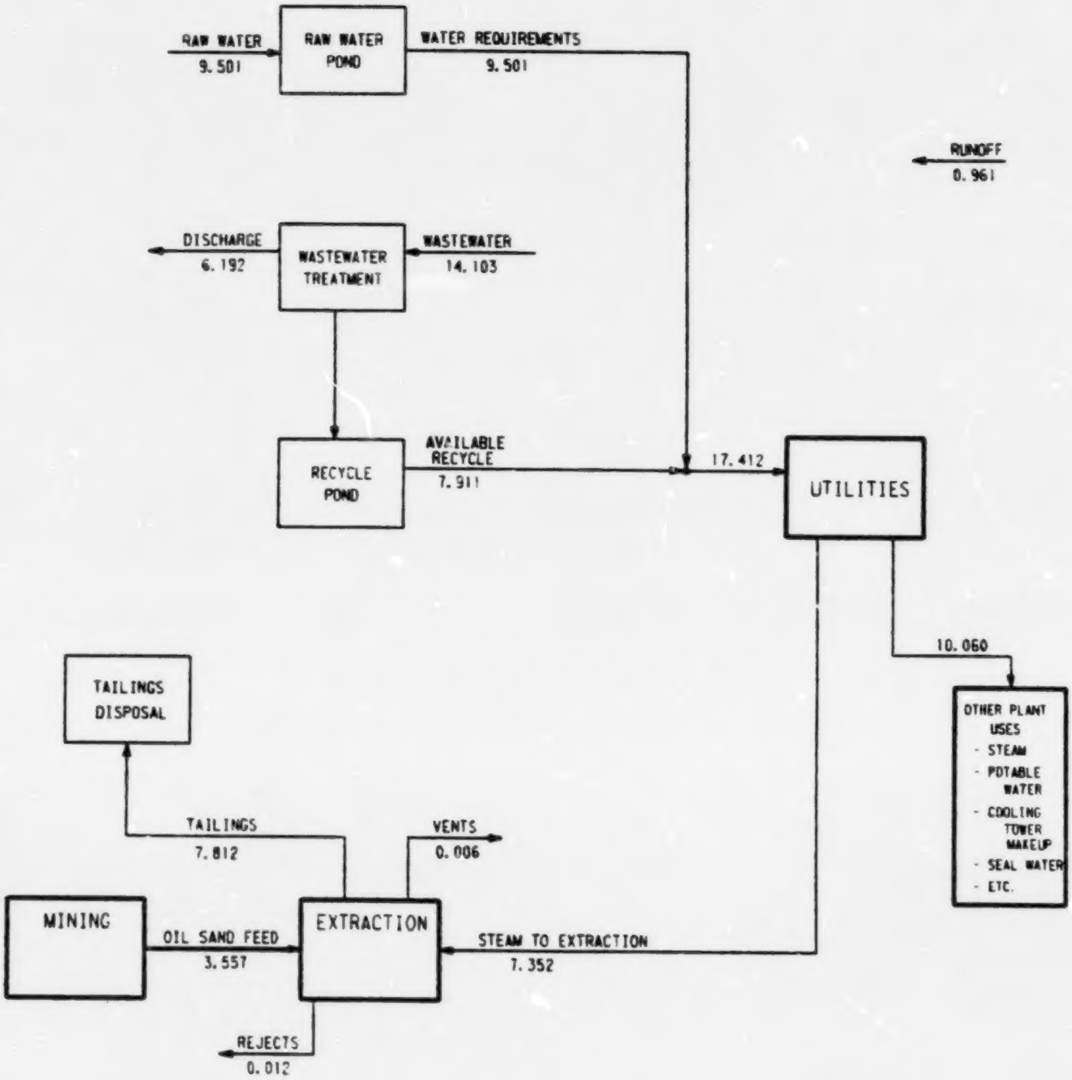
TABLE 5-25

Water Balance - Option 9(1)

Water	Input $m^3 x 10^6$	Output $m^3 x 10^6$
Raw Oil Sands Feed	3.557	
Rejects		0.012
Tailings		7.812
Steam to Extraction	7.352	
Extraction Wastewater		3.082
Extraction Vents		0.006
Runoff	0.961	
Wastewater		11.021
Available Recycle	7.911	
Other Raw Water Input	2.149	
Total	21.930	21.933

Notes: [1] Option 9 - Solvent Extraction/Flexicoking/Flexigas Boilers

WATER MANAGEMENT SCHEME


RAW WATER
9.501
RAW WATER POND
WATER REQUIREMENTS
9.501
RUNOFF
0.961
DISCHARGE
6.192
WASTEWATER TREATMENT
WASTEWATER
14.103
RECYCLE POND
AVAILABLE RECYCLE
7.911
17.412
UTILITIES
10.060
OTHER PLANT USES
- STEAM
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
TAILINGS DISPOSAL
TAILINGS
7.812
VENTS
0.006
MINING
OIL SAND FEED
3.557
EXTRACTION
STEAM TO EXTRACTION
7.352
REJECTS
0.012

UNITS: 10^6 CUBIC METRES PER YEAR

FIGURE 5-24

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 9 SOLVENT EXTRACTION/FLEXICOKING/
FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED

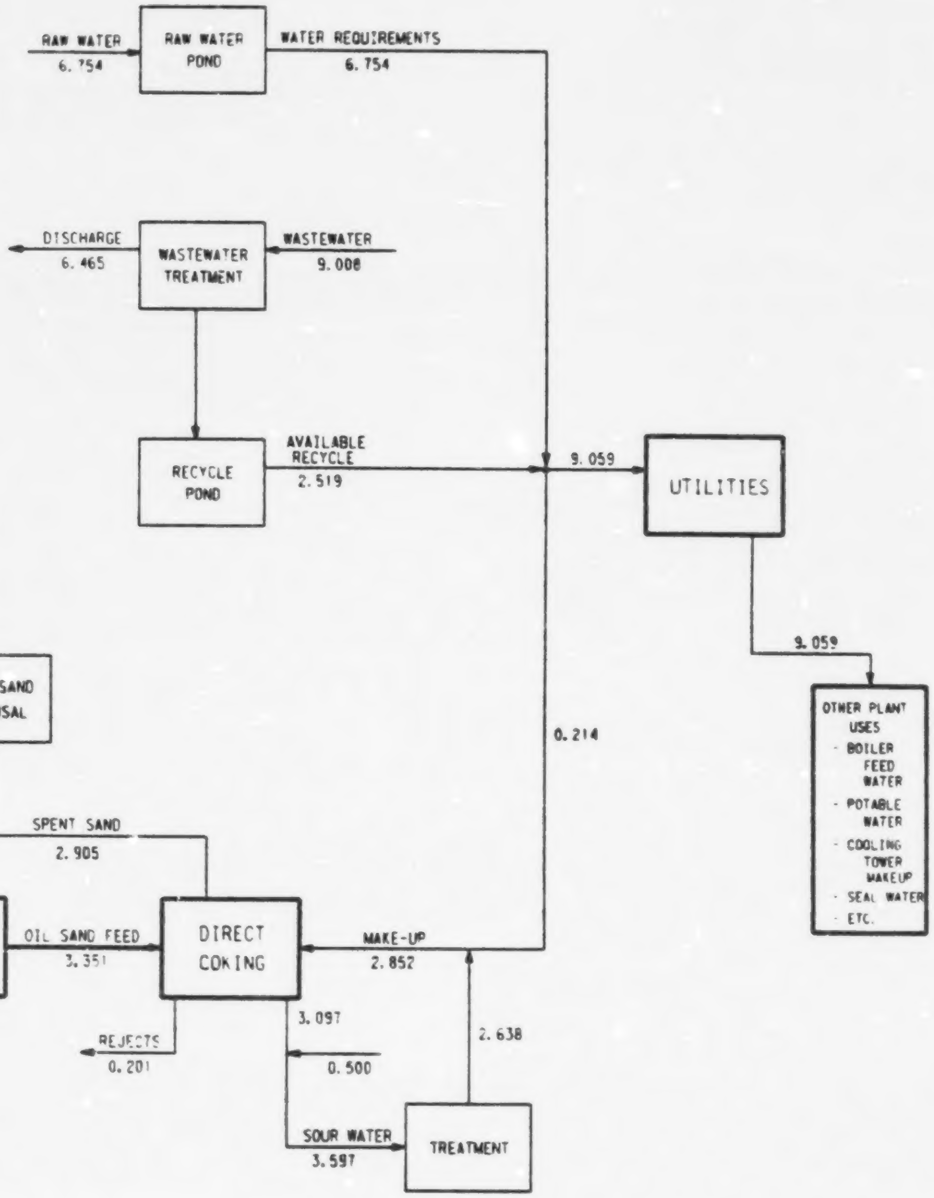
TABLE 5-26

Water Balance - Option 10(1)

Water	Input $m^3 x 10^6$	Output $m^3 x 10^6$
Raw Oil Sands Feed	3.351	
Rejects		0.201
Spent Sand		2.905
Recycle to Direct Coking	2.638	
Make-up to Direct Coking	0.214	
Sour Water		3.597
Runoff	0.699	
Wastewater		9.008
Available Recycle	2.519	
Other Raw Water Input	6.540	
Total	15.961	15.711

Notes: [1] Option 10 - Direct Coking

WATER MANAGEMENT SCHEME


RAW WATER
6.754
RAW WATER POND
WATER REQUIREMENTS
6.754
DISCHARGE
6.465
WASTEWATER TREATMENT
WASTEWATER
9.008
RECYCLE POND
AVAILABLE RECYCLE
2.519
9.059
UTILITIES
9.059
OTHER PLANT USES
- BOILER FEED WATER
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
SPENT SAND DISPOSAL
0.214
SPENT SAND
2.905
MINING
OIL SAND FEED
3.351
DIRECT COKING
MAKE-UP
2.852
REJECTS
0.201
3.097
0.500
2.638
SOUR WATER
3.597
TREATMENT

UNITS: 10^6 CUBIC METRES PER YEAR

FIGURE 5-25

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 10 DIRECT COKING

MONENCO CONSULTANTS LIMITED

TABLE 5-27

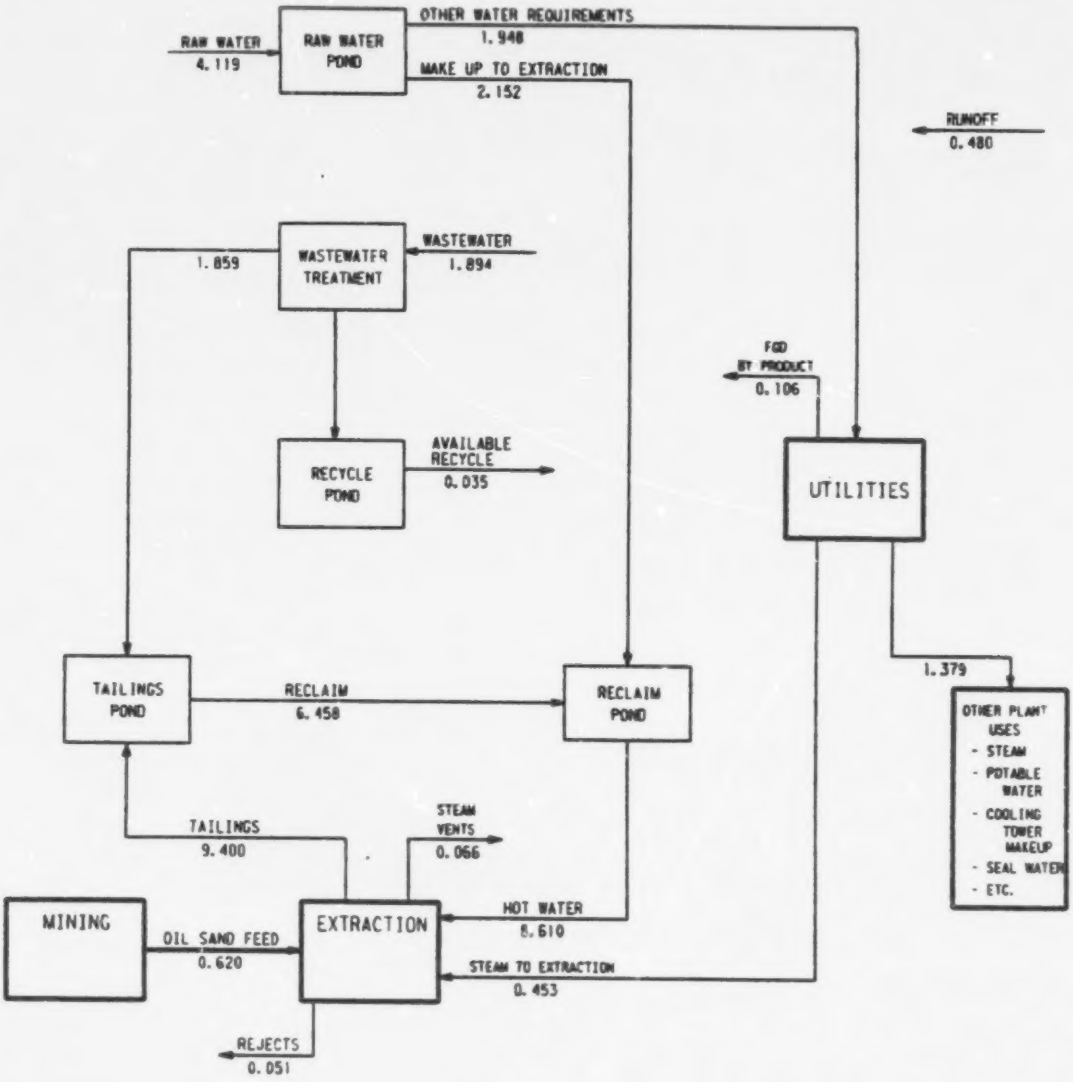
Water Balance - Option 11(1)

Water	Input $m^3 x 10^6$	Output $m^3 x 10^6$
Raw Oil Sands Feed	0.620	
Rejects		0.051
Steam to Extraction	0.453	
Reclaim from Tailings Pond	6.458	
Make-up to Extraction	2.152	
Tailings		9.400
Runoff	0.480	
Wastewater		1.894
Vents		0.066
Available Recycle	0.035	
Other Raw Water Input	1.379	
Net Make-up to FGD	0.116	
FGD Byproduct		0.106
Total	11.693	11.517

Notes: [1] Option 11 - Hot Water Extraction/Fluid Coking/CO and Coke Boilers

MONENCO CONSULTANTS LIMITED

WATER MANAGEMENT SCHEME


RAW WATER
4.119
RAW WATER POND
OTHER WATER REQUIREMENTS
1.948
MAKE UP TO EXTRACTION
2.152
RUNOFF
0.480
WASTEWATER TREATMENT
1.859
WASTEWATER
1.894
FGD BY PRODUCT
0.106
RECYCLE POND
AVAILABLE RECYCLE
0.035
UTILITIES
TAILINGS POND
RECLAIM
6.458
RECLAIM POND
1.379
OTHER PLANT USES
- STEAM
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
TAILINGS
9.400
STEAM VENTS
0.066
MINING
OIL SAND FEED
0.620
EXTRACTION
HOT WATER
8.610
STEAM TO EXTRACTION
0.453
REJECTS
0.051

UNITS: 10^6 CUBIC METRES PER YEAR

FIGURE 5-26

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 11 HOT WATER EXTRACTION/FLUID COKING/
CO & COKE BOILERS

MONENCO CONSULTANTS LIMITED

TABLE 5-28

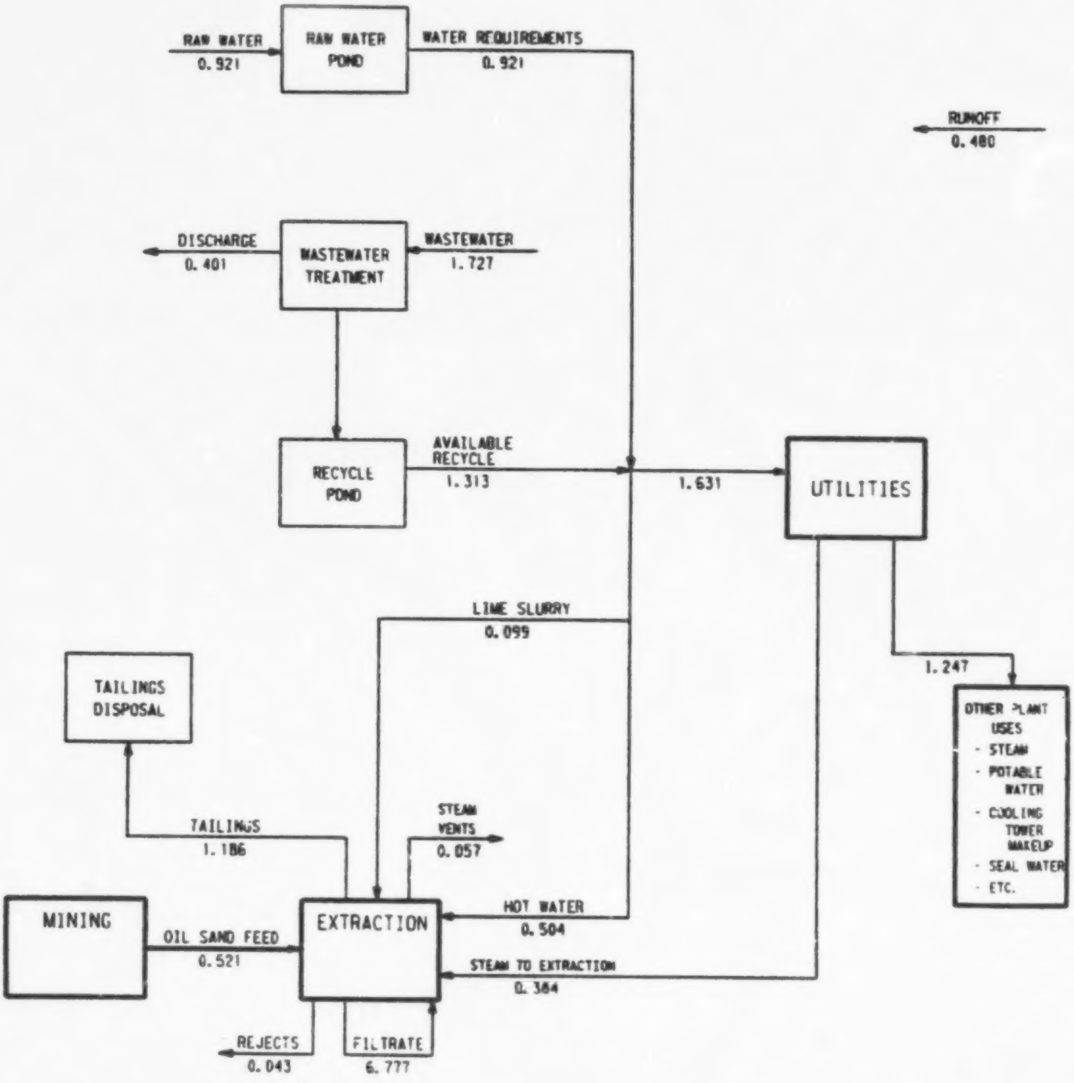
Water Balance - Option 12(1)

Water	Input m^3x10^6	Output m^3x10^6
Raw Oil Sands Feed	0.521	
Rejects		0.043
Extraction Make-up	0.504	
Steam to Extraction	0.384	
Lime Slurrying - Tailings Filtration	0.099	
Tailings		1.186
Filtrate	6.777	6.777
Runoff	0.480	
Available Recycle Water	1.313	
Other Raw Water Input	0	
Wastewater		1.727
Vents		0.057
Total	10.078	9.790

Notes: [1] Option 12 - Hot Water Extraction/Tailings Filtration/H-Oil/ Partial Oxidation of Pitch

MONENCO CONSULTANTS LIMITED

WATER MANAGEMENT SCHEME


RAW WATER
0.921
RAW WATER POND
WATER REQUIREMENTS
0.921
RUNOFF
0.480
DISCHARGE
0.401
WASTEWATER TREATMENT
WASTEWATER
1.727
RECYCLE POND
AVAILABLE RECYCLE
1.313
1.631
UTILITIES
LIME SLURRY
0.099
1.247
OTHER PLANT USES
- STEAM
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
TAILINGS DISPOSAL
TAILINGS
1.186
STEAM VENTS
0.057
MINING
EXTRACTION
HOT WATER
0.504
OIL SAND FEED
0.521
STEAM TO EXTRACTION
0.384
REJECTS
0.043
FILTRATE
6.777

UNITS: 10^6 CUBIC METRES PER YEAR

FIGURE 5-27

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 12 HOT WATER EXTRACTION/TAILINGS
FILTRATION/H-OIL/
PARTIAL OXIDATION OF PITCH

MONENCO CONSULTANTS LIMITED

TABLE 5-29

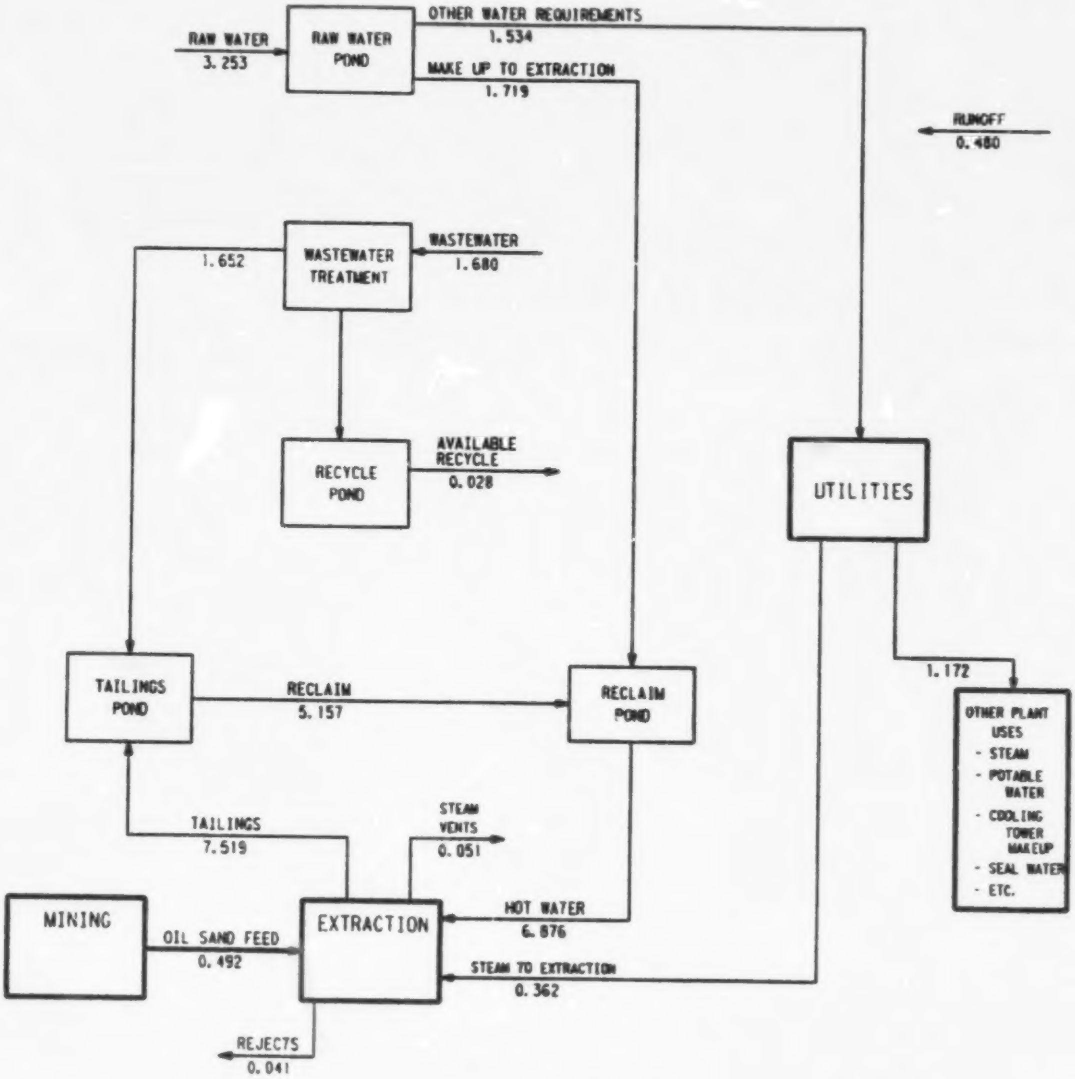
Water Balance - Option 13(1)

Water	Input m^3x10^6	Output m^3x10^6
Raw Oil Sands Feed	0.492	
Rejects		0.041
Steam to Extraction	0.362	
Reclaim from Tailings Pond	5.157	
Make-up to Extraction	1.719	
Tailings		7.519
Runoff	0.480	
Wastewater		1.680
Vents		0.051
Available Recycle Water	0.028	
Other Raw Water Input	1.172	
Total	9.410	9.291

Notes: [1] Option 13 - Hot Water Extraction/CANMET/Pitch Boilers (FBC)

MONENCO CONSULTANTS LIMITED

WATER MANAGEMENT SCHEME


RAW WATER
3.253
RAW WATER POND
OTHER WATER REQUIREMENTS
1.534
MAKE UP TO EXTRACTION
1.719
RUNOFF
0.480
WASTEWATER TREATMENT
1.652
WASTEWATER
1.680
RECYCLE POND
AVAILABLE RECYCLE
0.028
UTILITIES
TAILINGS POND
RECLAIM
5.157
RECLAIM POND
1.172
OTHER PLANT USES
- STEAM
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
TAILINGS
7.519
STEAM VENTS
0.051
MINING
OIL SAND FEED
0.492
EXTRACTION
HOT WATER
6.876
STEAM TO EXTRACTION
0.362
REJECTS
0.041

UNITS: 10^6 CUBIC METRES PER YEAR

FIGURE 5-28

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS FROM A MINING OIL SANDS COMPLEX

OPTION 13 HOT WATER EXTRACTION/CANMET/PITCH BOILERS (FBC)

MONENCO CONSULTANTS LIMITED

TABLE 5-30

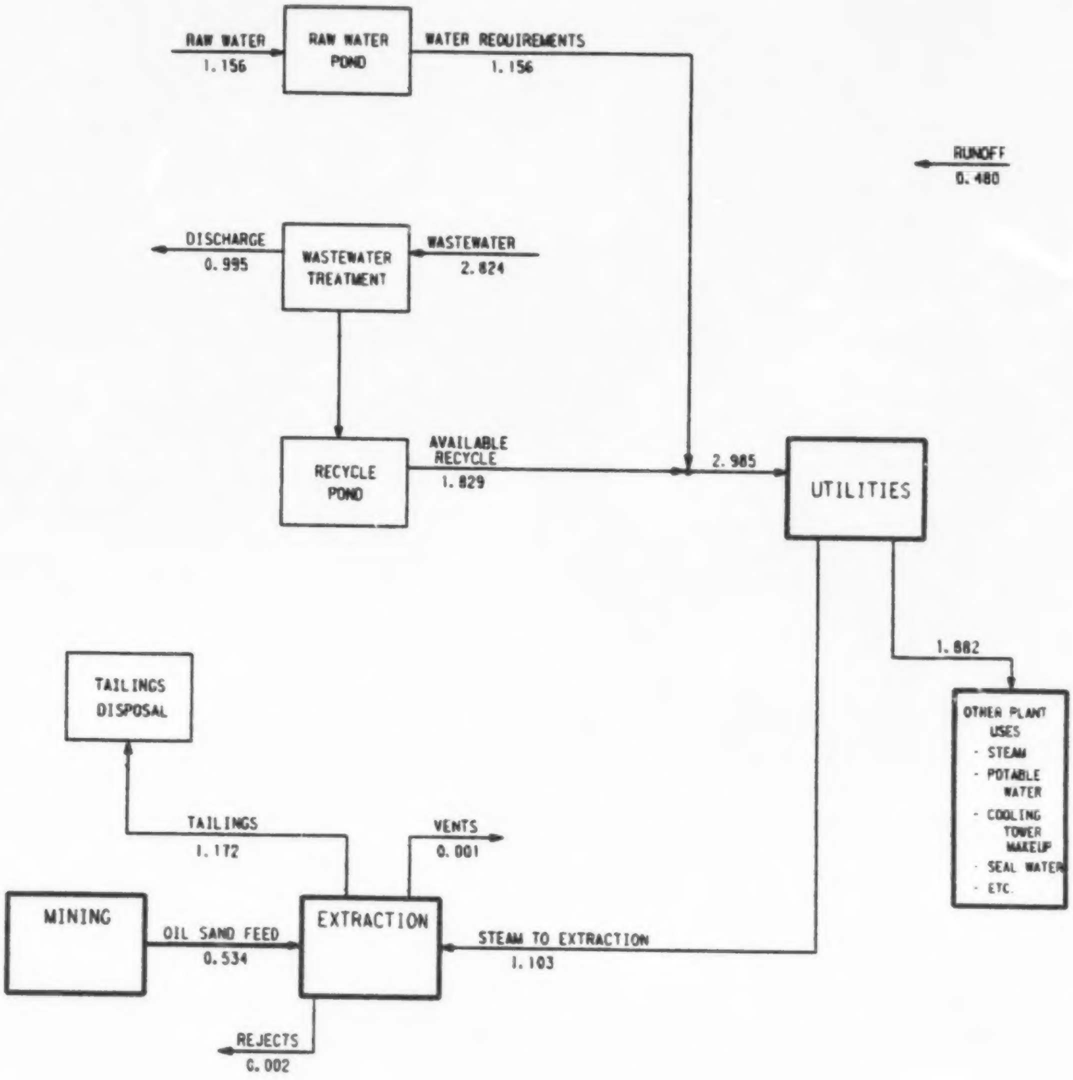
Water Balance - Option 14(1)

Water	Input m^3x10^6	Output m^3x10^6
Raw Oil Sands Feed	0.534	
Rejects		0.002
Tailings		1.172
Steam to Extraction	1.103	
Extraction Wastewater		0.462
Extraction Vents		0.001
Runoff	0.480	
Wastewater		2.362
Available Recycle	1.829	
Other Raw Water Input	0.053	
Total	3.999	3.999

Notes: [1] Option 14 - Solvent Extraction/Flexicoking/Flexigas Boilers

MONENCO CONSULTANTS LIMITED

WATER MANAGEMENT SCHEME


RAW WATER
1.156
RAW WATER POND
WATER REQUIREMENTS
1.156
RUNOFF
0.480
DISCHARGE
0.995
WASTEWATER TREATMENT
WASTEWATER
2.824
RECYCLE POND
AVAILABLE RECYCLE
1.829
2.985
UTILITIES
1.882
OTHER PLANT USES
- STEAM
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
TAILINGS DISPOSAL
TAILINGS
1.172
VENTS
0.001
MINING
OIL SAND FEED
0.534
EXTRACTION
STEAM TO EXTRACTION
1.103
REJECTS
0.002

UNITS: 10^6 CUBIC METRES PER YEAR

FIGURE 5-29

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 14 SOLVENT EXTRACTION/FLEXICOKING/
FLEXIGAS BOILERS

MONENCO CONSULTANTS LIMITED

TABLE 5-31

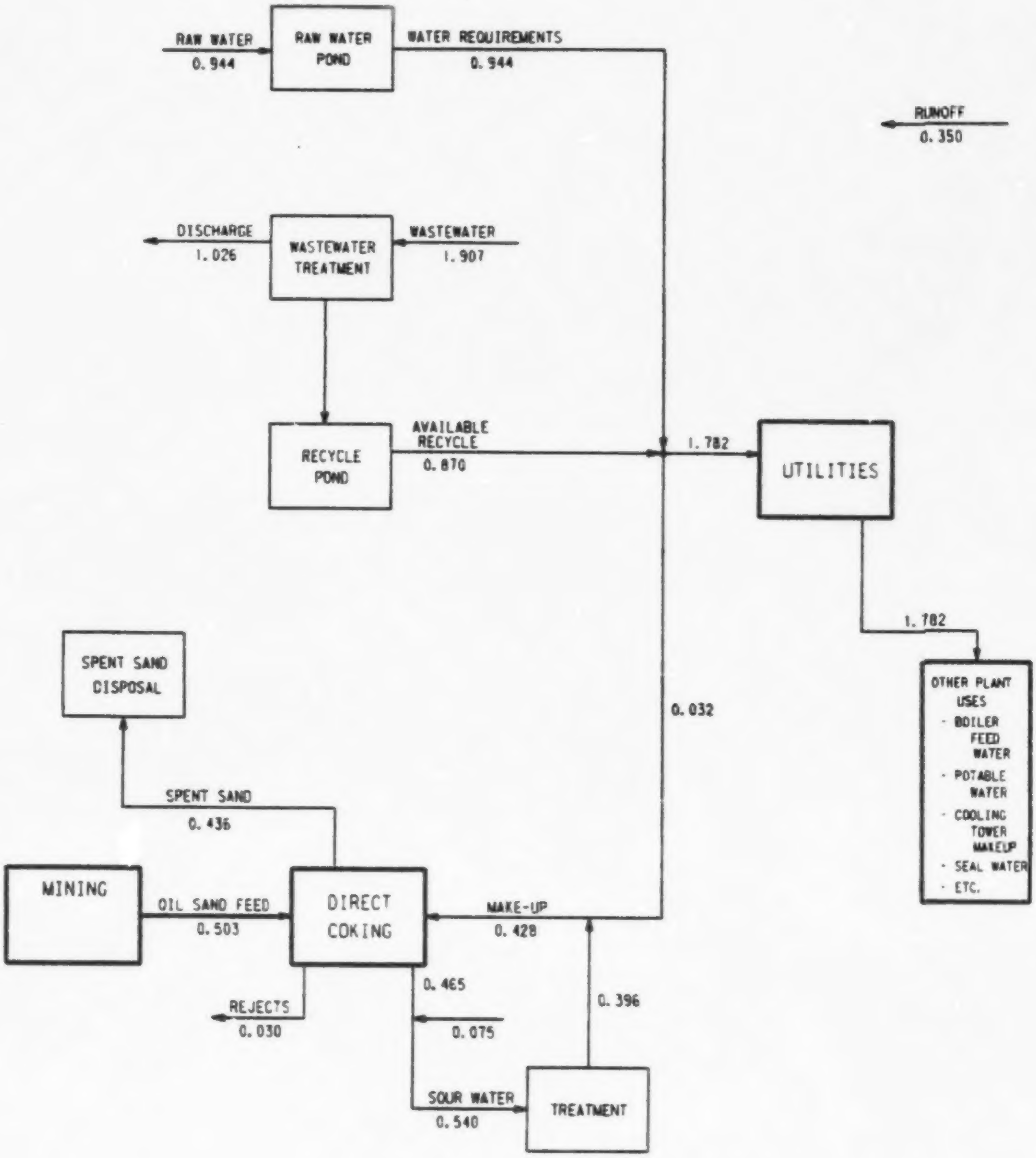
Water Balance - Option 15(1)

Water	Input m^3x10^6	Output m^3x10^6
Raw Oil Sands Feed	0.503	
Rejects		0.030
Spent Sand		0.436
Recycle to Direct Coking	0.396	
Make-up to Direct Coking	0.032	
Sour Water		0.540
Runoff	0.350	
Wastewater		1.907
Available Recycle	0.870	
Other Raw Water Input	0.912	
Total	3.163	2.913

Notes: [1] Option 15 - Direct Coking

MONENCO CONSULTANTS LIMITED

WATER MANAGEMENT SCHEME


RAW WATER
0.944
RAW WATER POND
WATER REQUIREMENTS
0.944
RUNOFF
0.350
DISCHARGE
1.026
WASTEWATER TREATMENT
WASTEWATER
1.907
RECYCLE POND
AVAILABLE RECYCLE
0.870
1.782
UTILITIES
1.782
OTHER PLANT USES
- BOILER FEED WATER
- POTABLE WATER
- COOLING TOWER MAKEUP
- SEAL WATER
- ETC.
SPENT SAND DISPOSAL
0.032
SPENT SAND
0.436
MINING
OIL SAND FEED
0.503
DIRECT COKING
MAKE-UP
0.428
0.465
REJECTS
0.030
0.075
0.396
SOUR WATER
0.540
TREATMENT

UNITS: 10^6 CUBIC METRES PER YEAR

FIGURE 5-30

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE

CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

OPTION 15 DIRECT COKING

MONENCO CONSULTANTS LIMITED

PART 6

COST ESTIMATES

PART 6 - COST ESTIMATES

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6.1 INTRODUCTION

Capital cost estimates for wastewater treatment systems and flue gas treatment systems have been estimated from published data (EPA (1976), EPA (1979), EPA (1980)) supplemented by in-house information. The costs include design, purchase of equipment, installation, buildings, camps and indirect costs. The estimates do not include the cost of sewers or transmission mains, although the cost of in-plant piping and pumping is included. In all cases, the estimated costs have been adjusted to January 1983 cost base and reflect Canadian conditions. The costs should be viewed as being suitable only for comparison of concepts.

The cost estimates for wastewater treatment systems are considered accurate to ±25 percent. For the flue gas treatment systems, costs are considered less precise.

The disposal costs for solid wastes are very site specific with most of the materials disposed of as backfill in the mine. In this case, the cost of trucking and spreading of the material is given on a per tonne basis to give an indication rather than absolute cost of solid waste disposal.

6.2 WASTEWATER TREATMENT SYSTEMS

As described in Section 4.5, the treatment systems are made up of several treatment components. For each of the components, the total direct construction cost was determined on the basis of design flow, capacity or loading rate. The direct cost includes excavation and site-work, manufactured equipment, concrete, steel, labour, component piping and valves, electrial equipment and instrumentation, buildings and other miscellaneous items.

The direct installed costs were adjusted to January 1983 cost base. The adjustments were made by utilizing the ENR Construction Cost Index, Chemical Engineering Plant Cost Index and the EPA Construction Cost Index (LCAT). Indirect construction costs (field costs, contractor's overhead and profits, etc.), home office costs (design, engineering, etc.) and contingencies were then added to the total direct costs to provide the total project costs for the wastewater treatment facilities.

The following summarizes the assumptions and escalation factors used in the determination of total project costs:

1. The ENR Construction Cost Index for January 1983 is 370.99 (base year 1967) or 3985.15 (base year 1913).

2. The Chemical Engineering Plant Cost Index for January, 1983 is 318.2.

3. The EPA Construction Cost Index (LCAT) for the 3rd quarter 1982 is 205.9 (national average). Index for January 1983 was assumed to be 211.6.

4. Published construction costs for lined ponds have been assumed to include purchase and installation of polyethylene liners. Additional purchase and installation costs for hypalon liners have been included for all ponds.

5. Hypalon liners on all ponds are protected by a layer of sand, 15 cm in thickness.

6. Total indirect construction costs are estimated to be 60% to 65% of total direct costs based on in-house data.

7. Home office costs are 12% of total field costs (direct plus indirect).

8. Contingencies are 17% of the total of all preceding costs.

9. Sewer line costs are not included in the estimates.

10. Exchange factor for converting American dollars to Canadian dollars is 1.23.

Tables 6-1 to 6-15 summarize the capital cost estimates for all options.

621 WASTEWATER TREATMENT SYSTEMS - TAILINGS POND OPTIONS (Options 1, 3, 4, 6, 7, 11 and 13)

Tables 6-1, 6-3, 6-4, 6-6 and 6-7 summarize the construction costs including direct costs, indirect construction costs, home office costs and contingencies for the tailings pond options at the higher synthetic crude production rate (20 000 m^3/d).

The primary factor affecting capital costs for these options is the process wastewater flows. These flows vary only slightly for the five options ranging from a low of 14 365 m^3/d (Option 6) to a high of 20 443 m^3/d (Option 7). The total costs for the five options average \$25.6 x 10^6 and range from \$24.3 x 10^6 to \$26.9 x 10^6.

Tables 6-11 and 6-13 summarize the total wastewater treatment system costs for a 3000 m^3/d oil sands complex with a tailings pond. The costs range from \$10.9 x 10^6 to \$11.2 x 10^6. The treatment systems costs for the 3000 m^3/d facilities are approximately 40 percent of the costs for the 20 000 m^3/d facilities.

TABLE 6-1

Capital Cost Estimate Summary[1]
Wastewater Treatment System
Option 1[2]

Component	Total Cost (10^3\$)
API Separator	812
Effluent Pond	355
Storm Pond	2 207
Sludge Pond	1 909
Recycle Pond	64
Reclaim Pond	3 265
Sewage Treatment Plant	2 837
In-Plant Lift Station	973
Total Direct Costs	12 422
Indirect Construction Costs (65%)	8 074
Total Field Costs	20 496
Home Office Costs @ 12%	2 459
Subtotal	22 955
Contingency @ 17%	3 902
Total Treatment System Cost	26 857

Notes: 1 All costs in January 1983 Canadian Dollars
2 Option 1 - Hot Water Extraction/Fluid Coking/CO and Coke Boilers

TABLE 6-2

Capital Cost Estimate Summary(1)
Wastewater Treatment System
Option 2(2)

Component	Total Cost (10^3\$)
API Separator	923
Dissolved Air Flotation	945
Activated Sludge	4 832
Dual Media Filtration	2 178
Storm Pond	2 207
Recycle Pond	590
Sludge Pond	4 413
Sediment Pond	172
Sewage Treatment Plant	2 837
In-Plant Lift Stations	1 767
Chemical Feed Systems	199
Total Direct Costs	21 063
Indirect Construction Costs (60%)	12 638
Total Field Costs	33 701
Home Office Costs @ 12%	4 044
Subtotal	37 745
Contingency @ 17%	6 417
Total Treatment System Cost	44 162

Notes: 1 All costs in January 1983 Canadian Dollars
2 Option 2 - Hot Water Extraction/Tailings Filtration/Fluid Coking/Gasification of Coke

TABLE 6-3

Capital Cost Estimate Summary(1)
Wastewater Treatment System
Option 3(2)

Component	Total Cost (10^3\$)
API Separator	812
Effluent Pond	355
Storm Pond	2 207
Sludge Pond	1 658
Recycle Pond	64
Reclaim Pond	3 265
Sewage Treatment Plant	2 837
In-Plant Lift Station	952
Total Direct Costs	12 150
Indirect Construction Costs (65%)	7 897
Total Field Costs	20 047
Home Office Costs @ 12%	2 405
Subtotal	22 452
Contingency @ 17%	3 816
Total Treatment System Cost	25 268

Notes: 1 All costs in January 1983 Canadian Dollars
2 Option 3 - Hot Water Extraction/Flexicoking/Flexigas Boilers

TABLE 6-4

Capital Cost Estimate Summary(1)
Wastewater Treatment System
Option 4(2)

Component	Total Cost (10^3\$)
API Separator	775
Effluent Poud	312
Storm Pond	2 207
Sludge Pond	1 909
Recycle Pond	64
Reclaim Pond	2 276
Sewage Treatment Plant	2 837
In-Plant Lift Station	882
Total Direct Costs	11 262
Indirect Construction Costs (65%)	7 319
Total Field Costs	18 581
Home Office Costs @ 12%	2 229
Subtotal	20 810
Contingency @ 17%	3 537
Total Treatment System Cost	24 347

Notes: 1 All costs in January 1983 Canadian Dollars
2 Option 4 - Hot Water Extraction/H-Oil/Pitch Boilers

TABLE 6-5

Capital Cost Estimate Summary(1)
Wastewater Treatment System
Option 5(2)

Component	Total Cost (10^3\$)
API Separator	794
Dissolved Air Flotation	870
Activated Sludge	4 217
Dual Media Filtration	1 968
Storm Pond	2 207
Recycle Pond	522
Sludge Pond	4 025
Sediment Pond	155
Sewage Treatment Plant	2 837
In-Plant Lift Stations	1 628
Chemical Feed Systems	190
Total Direct Costs	19 413
Indirect Construction Costs (60%)	11 648
Total Field Costs	31 061
Home Office Costs @ 12%	3 727
Subtotal	34 788
Contingency @ 17%	5 914
Total Treatment System Cost	40 702

Notes: 1 All costs in January 1983 Canadian Dollars
2 Option 5 - Hot Water Extraction/Tailings Filtration/H-Oil/Partial Oxidation of Pitch

TABLE 6-6

Capital Cost Estimate Summary(1)
Wastewater Treatment System
Option 6(2)

Component	Total Cost (10^3\$)
API Separator	775
Effluent Pond	312
Storm Pond	2 207
Sludge Pond	1 658
Recycle Pond	64
Reclaim Pond	2 612
Sewage Treatment Plant	2 837
In-Plant Lift Station	889
Total Direct Costs	11 354
Indirect Construction Costs (65%)	7 380
Total Field Costs	18 734
Home Office Costs @ 12%	2 248
Subtotal	20 982
Contingency @ 17%	3 567
Total Treatment System Cost	24 549

Notes: 1 All costs in January 1983 Canadian Dollars
2 Option 6 - Hot Water Extraction/CANMET/Pitch Boilers (FBC)

TABLE 6-7

Capital Cost Estimate Summary(1)

Component	Total Cost (10^3\$)
API Separator	1 122
Effluent Pond	392
Storm Pond	2 207
Sludge Pond	1 658
Recycle Pond	64
Reclaim Pond	3 165
Sewage Treatment Plant	2 837
In-Plant Lift Station	973
Total Direct Costs	12 418
Indirect Construction Costs (65%)	8 071
Total Field Costs	20 489
Home Office Costs @ 12%	2 458
Subtotal	22 947
Contingency @ 17%	3 901
Total Treatment System Cost	26 848

Notes: 1 All costs in January 1983 Canadian Dollars
2 Option 7 - Hot Water Extraction/Eureka/Gasification of Pitch

TABLE 6-8

Capital Cost Estimate Summary(1)
Wastewater Treatment System
Option 8(2)

Component	Total Cost (10^3\$)
API Separator	1 296
Dissolved Air Flotation	1 150
Activated Sludge	7 040
Dual Media Filtration	2 810
Storm Pond	2 207
Recycle Pond	815
Sludge Pond	4 989
Sediment Pond	168
Sewage Treatment Plant	2 837
In-Plant Lift Stations	1 981
Chemical Feed Systems	195
Total Direct Costs	25 488
Indirect Construction Costs (60%)	15 293
Total Field Costs	40 781
Home Office Costs @ 12%	4 893
Subtotal	4 5674
Contingency @ 17%	7 764
Total Treatment System Cost	53 438

Notes: 1 All costs in January 1983 Canadian Dollars

2 Option 8 - Solvent Extraction/Fluid Coking/CO Boilers/Coke Boilers (FBC)

TABLE 6-9

Capital Cost Estimate Summary(1)
Wastewater Treatment System
Option 9(2)

Component	Total Cost (10^3\$)
API Separator	1 322
Dissolved Air Flotation	1 172
Activated Sludge	7 190
Dual Media Filtration	2 890
Storm Pond	2 207
Recycle Pond	832
Sludge Pond	4 902
Sediment Pond	168
Sewage Treatment Plant	2 837
In-Plant Lift Stations	1 999
Chemical Feed Systems	196
Total Direct Costs	25 715
Indirect Construction Costs (60%)	15 429
Total Field Costs	41 144
Home Office Costs @ 12%	4 937
Subtotal	46 081
Contingency @ 17%	7 833
Total Treatment System Cost	53 914

Notes: 1 All costs in January 1983 Canadian Dollars
2 Option 9 - Solvent Extraction/Flexicoking/Flexigas Boilers

TABLE 6-10

Capital Cost Estimate Summary(1)
Wastewater Treatment System
Option 10(2)

Component	Total Cost ($10^3$$)
API Separator	554
Dissolved Air Flotation	665
Activated Sludge	2 830
Dual Media Filtration	1 533
Storm Pond	1 784
Recycle Pond	536
Sludge Pond	28 984
Sediment Pond	154
Biox Unit Incl. DAF and Thickners	3 026
Biox Storage Pond	150
Sewage Treatment Plant	2 837
In-Plant Lift Stations	1 209
Chemical Feed Systems	259
Total Direct Costs	44 421
Indirect Construction Costs (60%)	26 653
Total Field Costs	71 074
Home Office Costs @ 12%	8 529
Subtotal	79 603
Contingency @ 17%	13 532
Total Treatment System Cost	93 135

Notes: 1 All costs in January 1983 Canadian Dollars
2 Option 10 - Direct Coking

TABLE 6-11

Capital Cost Estimate Summary(1)
Wastewater Treatment System
Option 11(2)

Component	Total Cost (10^3\$)
API Separator	406
Effluent Pond	95
Storm Pond	1 232
Sludge Pond	999
Recycle Pond	14
Reclaim Pond	621
Sewage Treatment Plant	1 419
In-Plant Lift Station	407
Total Direct Costs	5 193
Indirect Construction Costs (65%)	3 375
Total Field Costs	8 568
Home Office Costs @ 12%	1 028
Subtotal	9 596
Contingency @ 17%	1 631
Total Treatment System Cost	11 227

Notes: 1 All costs in January 1983 Canadian Dollars
2 Option 11 - Hot Water Extraction/Fluid Coking/CO and Coke Boilers

TABLE 6-12

Capital Cost Estimate Summary(1)
Wastewater Treatment System
Option 12(2)

Component	Total Cost (10^3\$)
API Separator	425
Dissolved Air Flotation	409
Activated Sludge	1 485
Dual Media Filtration	894
Storm Pond	1 228
Recycle Pond	219
Sludge Pond	1 998
Sediment Pond	43
Sewage Treatment Plant	1 419
In-Plant Lift Stations	717
Chemical Feed Systems	150
Total Direct Costs	8 987
Indirect Construction Costs (60%)	5 392
Total Field Costs	14 379
Home Office Costs @ 12%	1 725
Subtotal	16 104
Contingency @ 17%	2 738
Total Treatment System Cost	18 842

Notes: 1 All costs in January 1983 Canadian Dollars
2 Option 12 - Hot Water Extraction/Tailings Filtration/H-Oil/Partial Oxidation of Pitch

TABLE 6-13

Capital Cost Estimate Summary(1)
Wastewater Treatment System
Option 13(2)

Component	Total Cost (10^3\$)
API Separator	406
Effluent Pond	95
Storm Pond	1 232
Sludge Pond	999
Recycle Pond	14
Reclaim Pond	497
Sewage Treatment Plant	1 419
In-Plant Lift Station	396
Total Direct Costs	5 058
Indirect Construction Costs (65%)	3 287
Total Field Costs	8 345
Home Office Costs @ 12%	1 002
Subtotal	9 347
Contingency @ 17%	1 589
Total Treatment System Cost	10 936

Notes: 1 All costs in January 1983 Canadian Dollars
2 Option 13 - Hot Water Extraction/CANMET/Pitch Boilers (FBC)

TABLE 6-14

Capital Cost Estimate Summary$^{(1)}$
Wastewater Treatment System
Option 14$^{(2)}$

Component	Total Cost (10^3\$)
API Separator	462
Dissolved Air Flotation	460
Activated Sludge	1 850
Dual Media Filtration	1 020
Storm Pond	1 228
Recycle Pond	281
Sludge Pond	1 833
Sediment Pond	51
Sewage Treatment Plant	1 419
In-Plant Lift Stations	731
Chemical Feed Systems	139
Total Direct Costs	9 474
Indirect Construction Costs (60%)	5 685
Total Field Costs	15 159
Home Office Costs @ 12%	1 819
Subtotal	16 978
Contingency @ 17%	2 886
Total Treatment System Cost	19 864

Notes: 1 All costs in January 1983 Canadian Dollars
2. Option 14 - Solvent Extraction/Flexicoking/Flexigas Boilers

TABLE 6-15

Capital Cost Estimate Summary(1)
Wastewater Treatment System
Option 15(2)

Component	Total Cost (10^3\$)
API Separator	332
Dissolved Air Flotation (DAF)	332
Activated Sludge	1 170
Dual Media Filtration	767
Storm Pond	1 094
Recycle Pond	183
Sludge Pond	5 018
Sediment Pond	45
Biox Unit Incl. DAF and Thickeners	572
Biox Storage Pond	38
Sewage Treatment Plant	1 419
In-Plant Lift Stations	522
Chemical Feed Systems	197
Total Direct Costs	11 689
Indirect Construction Costs (60%)	7 014
Total Field Costs	18 703
Home Office Costs @ 12%	2 244
Subtotal	20 947
Contingency @ 17%	3 561
Total Treatment System Cost	24 508

Notes: 1 All costs in January 1983 Canadian Dollars
2 Option 15 - Direct Coking

622 WASTEWATER TREATMENT SYSTEMS - TAILINGS FILTRATION OPTIONS (Options 2, 5 and 12)

The wastewater treatment systems costs for Options 2, 5 and 12 are summarized in Table 6-2, 6-5 and 6-12 respectively. The treatment system costs for a 20 000 m^3/d oil sands complex vary between \$40.7 x 10^6 to \$44.2 x 10^6. The increase in costs over the tailings pond options is due mainly to the extra cost for dissolved air flotation, activated sludge, filtration, filtrate treatment/storage and increased sludge storage.

The costs for the 3000 m^3/d facility are approximately 42 percent of the costs for the 20 000 m^3/d facility.

623 WASTEWATER TREATMENT SYSTEMS - SOLVENT EXTRACTION OPTIONS (Options 8, 9 and 14)

Tables 6-8, 6-9 and 6-14 summarize the construction costs for Options 8, 9 and 14 respectively. The costs for a 20 000 m^3/d oil sands facility using either Options 8 or 9 average \$53 x 10^6. The increase in costs is due largely to the increase in the process waste sewer flows and the extra treatment facilities required to treat the wastewater in the absence of tailing pond.

The cost estimate for a 3000 m^3/d facility is approximately to \$19.9 x 10^6 which is about 39 percent of the cost for a 20 000 m^3/d facility.

624 WASTEWATER TREATMENT SYSTEMS - DIRECT COKING OPTIONS (Options 10 and 15)

Construction costs for wastewater treatment systems for Options 10 and 15 are summarized in Tables 6-10 and 6-15 respectively. The total wastewater treatment costs for Option 10 (20 000 m^3/d) are estimated to be \$93.1 x 10^6. Due to the significant volumes of sludge generated from the treatment of the direct coking sour water in Option 10, the sludge ponds have been sized for 5 year storage as opposed to 25 years storage for all other options. At the end of the five year period, the ponds will have to be dredged and prepared for future use.

The corresponding costs for a 3000 m^3/d facility are \$24.5 x 10^6.

6.3 SOLID WASTE DISPOSAL

The quantity of solid waste generated varies from option to option. The volume of solids from the extraction facilities which include rejects, dry tailings and spent sand are of sufficient magnitude to warrant a separate bulk handling system. As with the wet tailings, the disposal costs for these solids are not included in this study.

Sulphur is identified as a solid waste stream in the pollutant flow diagrams and waste management matrices. Because of its commercial value, it is assumed that all sulphur produced will be sold. Net coke is produced in Options 1 and 11 and net pitch in Option 4. Both products will be stockpiled on the site for potential reuse.

Table 6-16 identifies the quantity of waste solids generated by options. These solids consist of fly ash, bottom ash, spent bed materials from FBC boilers, softener solids from the utilities water treatment plant, char and fines from Flexicoking and slag and char from residue gasification. The largest quantity of waste is generated in Option 8 (Solvent Extraction/Fluid Coking/CO Boilers/Coke Boilers (FBC)) where approximately 2150 tonnes/sd of solids are generated.

For all options, it is assumed that solid wastes will be transported by trucks for disposal in the mine site. In the early stages of the oil sands plant operation, some solid wastes may have to be stored for short periods until such time as the reclamation plan is underway. This may require additional handling of the wastes with resultant increase in costs.

Disposal costs for solid wastes are very site specific and depend on the waste material, the mode of transport of the material, distance to the disposal site, rehandling of the material at the disposal site and method of disposal. In general, it is estimated that the cost of trucking will vary between $2 to 3 per tonne per km. Rehandling and spreading at the disposal site may be an additional $2 to 3 per tonne.

In all cases the disposal costs may be minimized by integrating reclamation and solid wastes disposal schemes so as to minimize rehandling of the wastes.

6.4 FLUE GAS TREATMENT

As identified in Section 4.4, flue gas treatment in the form of electrostatic precipitators and flue gas desulphurization (except FBC boilers) was required for all CO boilers and coke or pitch fired utility boilers.

TABLE 6-16

Solid Waste Generation(1)

Option	t/sd
1	260
2	410
3	770
4	230
5	380
6	540
7	290
8	2150
9	780
10	50
11	50
12	60
13	110
14	120
15	10

Note: (1) Includes fly ash, bottom ash, spent bed material (FBC boilers), softener solids (utilities water treatment plant), char and fines (Flexicoking) and slag and char (residue gasification).

641 ELECTROSTATIC PRECIPITATION

Cost estimates for electrostatic precipitators in this study have been based on a study conducted by Monenco Limited and Stearns-Roger Engineering Corporation (1982) for the three Alberta utilities companies. In the referenced study, cost estimates were for coal-fired power plants, therefore adjustments in the flue gas mass emission rate and total particulate emission rate were required. In general, it was assumed that the specific collection area is about 300 $m^2/m^3/s$ and that the resistivity of particulates in all flue gases is approximately the same. Each electrostatic precipitator is assumed to have a removal efficiency of 99%.

Table 6-17 presents a summary of the estimated capital costs.

642 FLUE GAS DESULPHURIZATION

Cost estimates for flue gas desulphurization by ammonia scrubbing are based on a study by Dynawest Projects Ltd. (1982) relative to a CO boiler. The estimates are presented in Table 6-18. The costs include reagent handling and storage, absorber, and waste handling and storage. Cost for the supply of ammonia is not included.

TABLE 6-17

Capital Cost Estimates(1)
Electrostatic Precipitator

Option(2)	Boiler	Total Cost (10^3\$)
1	CO	11 250
	Coke	30 000
2	CO	11 250
4	Pitch	14 750
6	Pitch	14 000
8	CO	11 250
	Coke	19 500
11	CO	6 250
	Coke	13 500
13	Pitch	5 000

Note: [1] All costs in Janary 1983 Canadian Dollars.

[2] Option 1 - Hot Water Extraction/Fluid Coking/CO and Coke Boilers
Option 2 - Hot Water Extraction/Tailings Filtration/Fluid Coking/Gasification of Coke
Option 4 - Hot Water Extraction/H-Oil/Pitch Boilers
Option 6 - Hot Water Extraction/CANMET/Pitch Boilers (FBC)
Option 8 - Hot Water Extraction/Fluid Coking/CO Boilers/Coke Boilers (FBC)
Option 11 - Hot Water Extraction/Fluid Coking/CO and Coke Boilers
Option 13 - Hot Water Extraction/CANMET/Pitch Boilers (FBC)

TABLE 6-18

Capital Cost Estimates(1)
Flue Gas Desulphurization(2)

Option(3)	Boiler	Cost ($10^3$$) Reagent Handling and Storage	Absorber	Waste Handling and Storage	Total
1	CO	340	44 375	290	45 005
	Coke	1115	122 500	840	124 455
2	CO	340	44 375	290	45 005
4	Pitch	945	51 175	785	52 905
8	CO	345	44 445	260	45 050
11	CO	140	16 625	115	16 880
	Coke	225	24 250	150	24 625

Note: [1] All costs in Janary 1983 Canadian Dollars.
[2] Ammonia Scrubbing
[3] Option 1 - Hot Water Extraction/Fluid Coking/CO and Coke Boilers
Option 2 - Hot Water Extraction/Tailings Filtration/Fluid Coking/Gasification of Coke
Option 4 - Hot Water Extraction/H-Oil/Pitch Boilers
Option 8 - Hot Water Extraction/Fluid Coking/CO Boilers/Coke Boilers (FBC)
Option 11 - Hot Water Extraction/Fluid Coking/CO and Coke Boilers

PART 7

SATELLITE PLANT ANALYSIS

PART 7 - SATELLITE PLANT ANALYSIS

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Figure

7-1 Satellite Mining Operations 7-2
7-2 Satellite Mining and Extraction Operations 7-4

7.1 INTRODUCTION

In Part 3, waste management data is provided for two sizes of oil sands complexes capable of producing synthetic crude at 20 000 and 3 000 cubic metres per day. Although this study did not involve a consideration of the capital costs associated with process operations of differing sizes, it is generally recognized in the oil and gas industry that there are substantial economies of scale associated with mining oil sands facilities. This is particularly true in the case of the upgrading processes. In order to take advantage of these economies of scale, while recognizing the nature of mineable oil sands, the use of satellite plants feeding into a major complex has been suggested. Satellite plants would assist in the staging of an overall mining oil sands process by allowing some revenues to be generated before completion of the entire complex.

There are two basic approaches to satellite operations:

1. a series of surface mining operations providing oil sands feed to a central extraction and upgrading facility; and
2. a series of surface mining and extraction operations providing bitumen feed to a central upgrading facility.

Each of these options is discussed below from a waste management standpoint.

7.2 SATELLITE OPERATIONS - MINING

The option of a number of surface mining operations providing oil sands feed to a central extraction and upgrading facility is shown in Figure 7-1. A materials handling problem will probably dictate that the extraction and upgrading facilities be located at the major mine feeding the plant. For the purposes of this discussion, it is assumed that six satellite mining operations each provide oil sands feed to a central extraction and upgrading facility with a synthetic crude production capacity of 20 000 m^3/d. Options for transport of the oil sands from the satellite facilities include conveyors, trucks and rail haul, however logistics and economics will generally preclude the use of trucks. As with a large mining oil sands facility, the oil sands from the various mining sites would be blended so as to maintain a constant oil sands feed quality. Oil sands feed rate from each of the satellite mines is approximately 450 kg/s.

Gaseous, liquid and solid waste emissions from the satellite mining operations include those emissions identified in Part 3 from mining operations feeding oil sands to a 3000 m^3/d oil sands complex (Options 11 to 15). These emissions include:

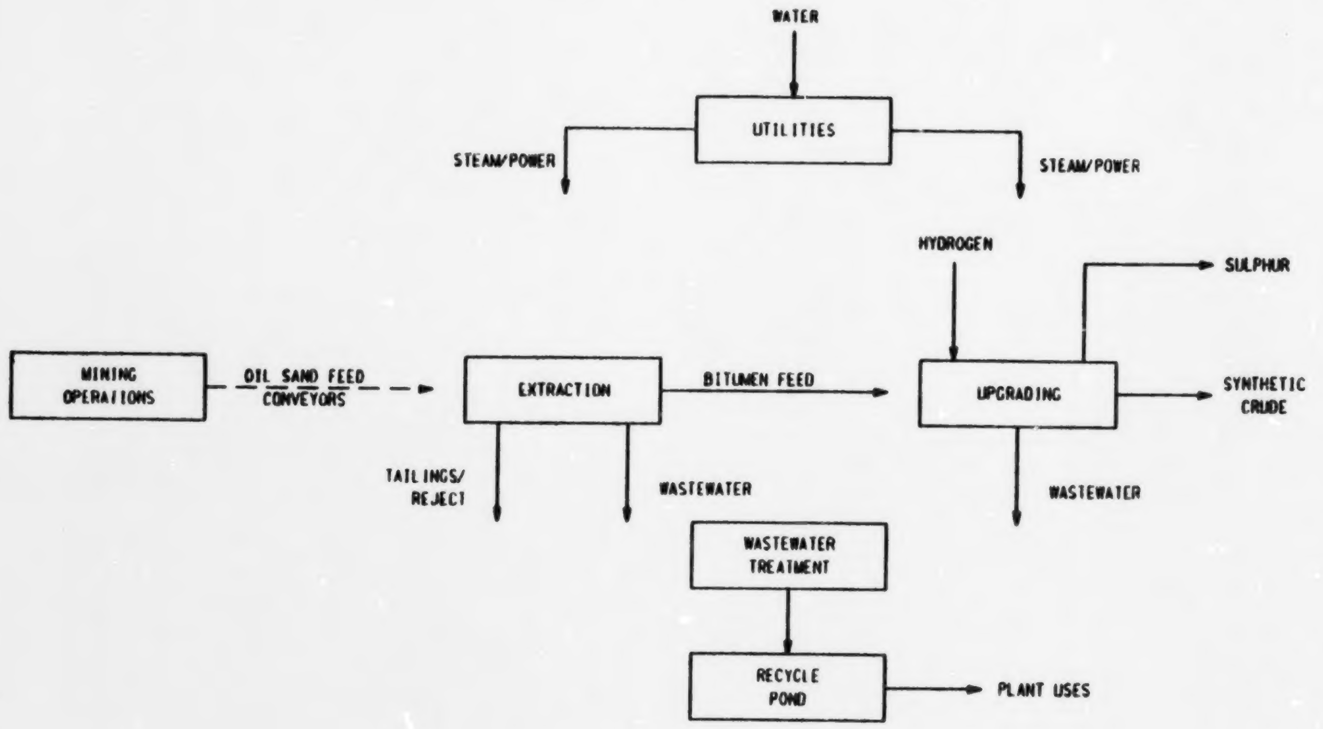
WATER
UTILITIES
STEAM/POWER
STEAM/POWER
HYDROGEN
SULPHUR
MINING OPERATIONS
OIL SAND FEED
CONVEYORS
EXTRACTION
BITUMEN FEED
UPGRADING
SYNTHETIC CRUDE
TAILINGS/ REJECT
WASTEWATER
WASTEWATER
WASTEWATER TREATMENT
RECYCLE POND
PLANT USES

FIGURE 7-1

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

SATELLITE MINING OPERATIONS

MONENCO CONSULTANTS LIMITED

N06262..PFD F24

- gaseous emissions and ash from site preparation;
- muskeg and subsoil;
- mine water, runoff and other wastewaters from dewatering programs, and
- emissions from diesel-powered excavators and vehicles and fugitive dust emissions.

In addition to the above, each of the satellite mining operations would require separate potable water and sewage treatment facilities. Self-contained equipment repair and maintenance facilities are required at each mine site. Electricity would be transmitted to the satellite mines from the utility plant at the central facility or from other power generation facilities.

The management of tailings from the central extraction facility creates logistical and environmental concerns, particularly for those extraction processes generating wet tailings. In the normal mine-plant configuration with a tailings pond, wet tailings are disposed of in the mine after about eight years of plant operations. With satellite mining operations, there will not likely be sufficient space within the mined-out area of the satellite mine located nearest to the central facility. Since it is considered impractical to return wet tailings to the satellite mines by a series of slurry pipelines, a large at-grade tailings pond would be required adjacent to the central facility.

For those extraction processes which generate dry tailings (hot water extraction with tailings filtration, solvent extraction and direct coking), the tailings would be transported back to the mine sites by conveyors, trucks or by rail. If the costs of dry tailings transport are prohibitive, dry tailings in excess of the quantity which can be economically disposed of in mine sites closest to the extraction plant, could be stockpiled on-site. Other solid wastes from upgrading, utilities and offsites would be transported to the mine sites for disposal.

7.3 SATELLITE OPERATIONS - MINING AND EXTRACTION

The option of a number of surface mining and extraction facilities providing bitumen feed to a central upgrading plant is shown in Figure 7-2. As in the previous case, a number of smaller mines might, in fact, provide oil sands feed to an extraction plant which in turn supplies a central upgrading plant. The upgrader could be located at a refinery operation which processes the synthetic crude into refined products.

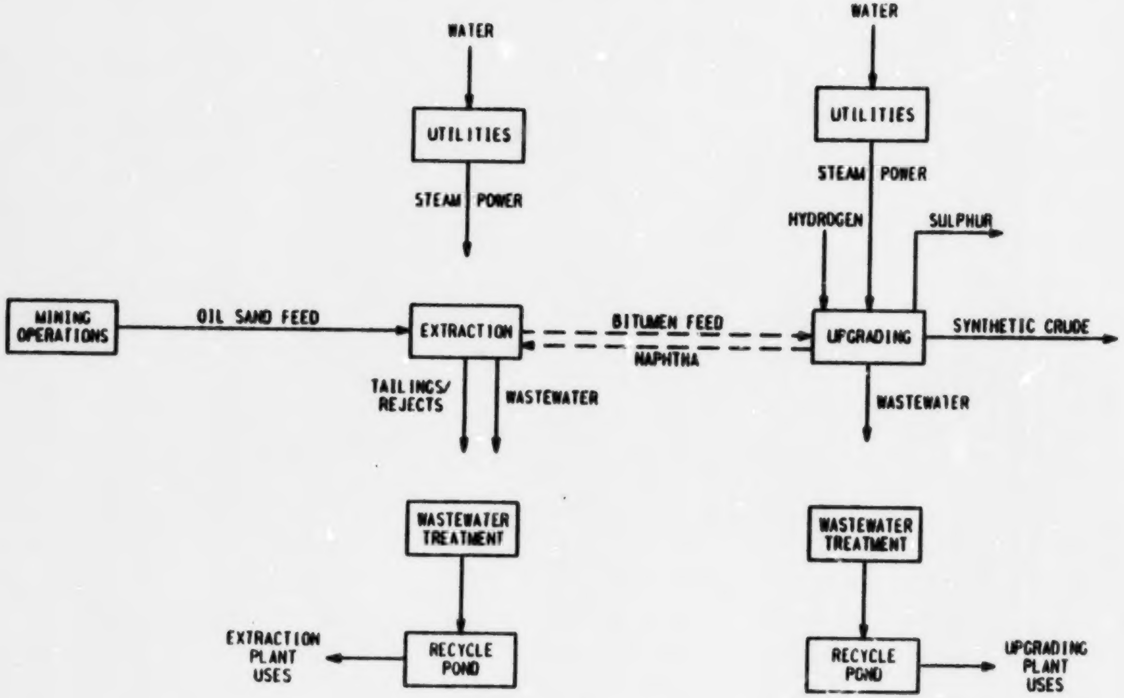
WATER
UTILITIES
STEAM
POWER
MINING OPERATIONS
OIL SAND FEED
EXTRACTION
BITUMEN FEED
NAPHTHA
TAILINGS/ REJECTS
WASTEWATER
WASTEWATER TREATMENT
RECYCLE POND
EXTRACTION PLANT USES
WATER
UTILITIES
STEAM
POWER
HYDROGEN
SULPHUR
UPGRADING
SYNTHETIC CRUDE
WASTEWATER
WASTEWATER TREATMENT
RECYCLE POND
UPGRADING PLANT USES

FIGURE 1-2

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
CHARACTERIZATION & TREATMENT OF EMISSIONS
FROM A MINING OIL SANDS COMPLEX

SATELLITE MINING AND
EXTRACTION OPERATIONS

MONENCO CONSULTANTS LIMITED

Whereas the cost of oil sands transport from satellite mining operations to a central extraction plant limits the aerial extent of these facilites, diluted bitumen from satellite extraction facilities could be pumped considerably greater distances to a central upgrading plant. The bitumen would have to be diluted with naphtha prior to pumping and, as the source of naphtha is the upgrading plant, a return pipeline to carry naphtha from upgrading to the extraction facilities is required.

There are waste management implications associated with the centralized upgrading facility. With upgrading operations located distant from the satellite mining and extraction facilities, the advantages of utilizing waste heat and residuals from primary upgrading and recycling wastewaters are lost. As well a nearby mine where solid wastes maybe disposed of will not be available. The central upgrading facility will require an extensive wastewater treatment plant with discharge of treated effluent. Nearby landfilling facilities would be required for the disposal of solid wastes.

The waste management implications of satellite mining and extraction facilities feeding bitumen to a central upgrader are identified in the following:

731 Hot Water Extraction with Tailings Pond

Satellite mining and hot water extraction facilities would generate gaseous, liquid and solid waste emissions as identified in Part 3. Waste management matrices (Tables 3-21 and 3-22) and the pollutant flow diagram (Figure 3-12) for Option 11 provide the waste characterization data for the satellite mining and extraction facilities.

Steam and hot water are required in the extraction plant and the use of waste heat and residuals from bitumen upgrading will not be available for this purpose. Accordingly, each satellite extraction plant will have its own utility plant consisting of raw water intake facilities, boiler feed water treatment, gas fired boilers and cooling facilities. Resultant waste emissions from the utility area include gaseous emissions from the boilers, sludges and regenerant wastewater from boiler feed water treatment and cooling tower and condensate blowdown. Each satellite mining and extraction facility would require potable water and sewage treatment facilites.

Interconnecting pipelines between the satellite facilities and the central updgrader include a major line for transporting diluted bitumen, a diluent return line and a pipeline for supplying natural gas and/or process gas required for steam production.

732 Hot Water Extraction with Tailings Filtration

Apart from eliminating the need for tailings ponds at the satellite mining and extraction facilities, filtration of the tailings provides no advantages over satellite mining and extraction with tailings ponds. Emissions from satellite facilities would be similar to Option 12 (see Tables 3-23 and 3-24 and Figure 3-13). A utility plant is required to provide boiler feed water, steam, hot water and cooling. Since a tailings pond is not available for disposal of wastewaters, wastewater treatment facilities are required prior to discharge of effluents to the environment.

733 Solvent Extraction

Tailings from solvent extraction are dry, hence these solids would be returned to the mining operations similar to Option 14. Gaseous, liquid and solid waste emissions from mining and extraction are provided in Tables 3-27 and 3-28 and Figure 3-15. Since steam is required in the solvent extraction process, a utility plant consisting of boiler feed water treatment, steam generation and cooling is required at the extraction facility. Water removed from the oil sands in the process, requires treatment prior to discharge, hence each satellite extraction plant will require an extensive wastewater treatment facility.

Diluted bitumen from the satellite facilities would be transported by pipeline to the central upgrading facility. A separate line is required to return solvent to extraction.

734 Direct Coking

In the direct coking process, upgrading of bitumen to intermediate liquid products takes place within the direct coking facilities. These intermediate products are relatively unstable, requiring secondary upgrading to produce products acceptable for storage or pipelining. Whereas the direct coking process may be an attractive alternative for smaller fully integrated facilities producing synthetic crude, it may not be practical or economical to have satellite direct coking facilities feeding a centralized secondary upgrading facility. Emissions from a fully integrated direct coking facility (3000 m^3/d) are provided in Part 3 for Option 15.

7.4 CONCLUSION

Overall, the construction of satellite facilities coupled to a central processing complex appears to result in increased gaseous, liquid and solid waste emissions when compared to the normal type of mining oil sands complex. Opportunities for the reuse of waste heat and recycling of residues and wastewater are lost because of the difficulty and cost associated with moving these surpluses between plant sites. The size of plant sites for satellite facilities and their attendant central processing plant will be somewhat larger than the site required for a single complex, resulting in increased volumes of runoff.

PART 8

CONCLUSIONS AND RECOMMENDATIONS

PART 8 - CONCLUSIONS AND RECOMMENDATIONS

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8.1 CONCLUSIONS

1. A review of the waste management data in this report indicates that there are significant data gaps, particularly in the emissions characterization data. Characterization information is very limited for trace elements and organic compounds in gaseous, liquid and solid waste emissions. Data collected from operating processes, either at the full or pilot scale, have been mainly oriented toward process performance. Characterization of emissions has tended to be of secondary concern. The exceptions are those pollutants which are, or will be, controlled by government requirements (e.g. SO_2, NO_x, phenol, etc.). In these cases, the emissions data base is somewhat more complete.

2. As required by the study terms of reference, waste management data in this report relate to mining oil sands processes operating under normal conditions. However, from a waste management standpoint, analysis of plant operations during upset conditions is critical because it is during upset conditions that liquid, gaseous and solid waste emissions are frequently at their maximum levels, putting waste handling and treatment facilities under maximum load conditions. Therefore, regulatory agency concerns are frequently associated with emissions under plant upset conditions. In light of the incomplete waste management data base, for processes under normal operating conditions, as identified above, it is believed that there is little or no relevant data for mining oil sands processes under upset conditions.

3. The increased utilization of solid residues from the primary upgrading processes is limited by the lack of demonstrated technology, particularly in the areas of coke or pitch gasification and steam raising using conventional boilers or fluidized bed boilers.

4. Operating experience for flue gas treatment under the severe operating conditions resulting from the utilization of by-product coke or pitch in conventional boilers is very limited.

5. As identified previously, there is a lack of wastewater characterization data and this is coupled with insufficient information on the treatability of these wastewaters. This is particularly the case for processes currently at the pilot scale, for example, direct coking and solvent extraction processes, and CANMET and Eureka upgrading processes.

6. The wastewater treatment system for the sour water from the Lurgi Ruhrgas Direct Coking Process has been established on the basis of limited data. There are concerns with respect to the treatment and disposal or recovery of the fatty acids. The wastewater treatment system established for this waste stream, and subsequent costs should be viewed as very preliminary. For practical reasons, alternative treatment/recovery methods are required, but must be analyzed with the benefit of complete wastewater characterization data.

7. A review of the pollutant flow diagrams indicates the extensive nature of the wastewater treatment systems for those options without a tailings pond. It is our belief that, while there is demonstrated treatment technology suitable to treat these wastewaters for either reuse or direct discharge, the size and scale of the treatment systems coupled with the lack of emissions data for process upset conditions will create numerous design, construction and operational problems.

8. All the options considered in this study rely on water recycle or reuse to a certain extent. Information on acceptable water quality for recycle or reuse in a process area is incomplete at best. Further, the long-term implications of wastewater recycle and reuse on overall process water quality have not been examined.

9. Comparison of capital costs for wastewater treatment between tailings pond options, tailings filtration options, solvent extraction options and direct coking options may not be applicable since some of the processes include pretreatment of wastes. Also, as identified above, the costs for the direct coking options are very sensitive to the treatment of the direct coking sour water. In general, it can be concluded that for similar capacity oil sands complexes, the costs for wastewater treatment systems for tailings pond options (1, 3, 4, 6, 7, 11 and 13) are approximately 50% of the treatment costs for tailings filtration options (2, 5 and 12) and solvent extraction options (8, 9 and 14). The treatment costs for options with tailings filtration and solvent extraction range between \$44 x 10^6 to \$54 x 10^6 for 20 000 m^3/d capacity complexes with costs for solvent extraction options tending towards the higher figure because of greater wastewater flows.

10. There are considerable economies of scale associated with the capital cost of wastewater treatment facilities. The synthetic crude production rate for the smaller oil sands complexes is 15% of the rate for the larger complexes, however, the capital costs for wastewater treatment are in the order of 40% of the costs for the larger complexes providing similar levels of treatment in each case.

8.2 RECOMMENDATIONS

1. Many of the conclusions of this report relate to the lack of waste management information (characterization and treatment) for the processes selected for the 15 options. The major recommendation of this report is, therefore, that steps be taken to improve the waste management information base. During this study, a detailed and extensive review of the available literature has been completed. It is our view that further literature reviews at this time will provide little or no useful additional waste management data. Other sources of information which should be pursued are the existing relevant full or pilot scale operations as well as licensor or proprietory information. This data base may, however, only be available on payment of a fee.

Further, it is recommended that in order to obtain a useful waste management data base, the government encourage those companies operating pilot scale facilities in Canada to collect and characterize any gaseous, liquid or solid waste emissions. In this regard, to ensure that the collected emissions information is useful, the government should prepare a sampling and analytical manual for use by the companies operating pilot facilities. It is further recommended that the Federal and Provincial governments cooperate in this data gathering exercise.

2. This study provided detailed waste management information for 15 mining oil sands options made up of selected processes which are either commercially proven or demonstrated at the pilot scale. However, a number of promising and emerging technologies were not included in the 15 options. It is, therefore, recommended that this study be extended to look at a number of other processes currently under development. In addition, a number of different process configurations (options) should be reviewed from a waste management standpoint. This is particularly the case for options with a production of between 1,000 and 3,000 m^3/d of synthetic crude.

3. This study has permitted the development of a computer-based system for the easy handling and manipulation of waste management data for a wide variety of different processes applicable to the mining, extraction and upgrading of oil sands and bitumen and their associated ancillary facilities. Recommendations relating to this computer-based information system include:

- the updating of the data base on a regular basis, for instance, every two years;
- the utilization of this system to store and manipulate waste management information obtained from other relevant studies and projects, as outlined above; and
- the expansion of this system to include cost data and waste management information from in situ heavy oil operations and heavy oil upgrading.

4. With respect to technology development and demonstration needs, the following are recommended:

- the utilization of residues from upgrading in conventional and fluidized bed boilers;
- the demonstration of a flue gas treatment system for the severe operating conditions associated with the utilization of by-product coke or pitch in conventional boilers; and
- the ability to continually recycle or reuse treated wastewaters in the processes and the effect of such systems on process performance and water treatment efficiency.

PART 9

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